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SOIL REACTION IN RELATION TO CALCIUM ADSORPTION[1]

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DISCUSSION OF TERMS AND STATEMENT OF THE PROBLEM

SOIL REACTION AND LIME REQUIREMENT

Various terms are found in soil literature relative to soil reaction. "Soil acidity" often refers to the reaction of moist soil toward some indicator such as litmus or phenolphthalein. "Lime requirement" refers to the amount of a calcium compound necessary to change the reaction to some chosen standard, usually the color change of phenolphthalein. The minimum amount of lime required to change the reaction to this standard is referred to as the "immediate lime requirement," while "continuous lime requirement" is an expression of the amount of lime needed to keep the soil at the desirable reaction for a period of time.

ACID, NEUTRAL, AND ALKALINE SOLUTIONS

The large amount of work done in recent years on hydrogen-ion concentration has served to clarify the meaning of the terms acid, neutral, and alkaline. All aqueous solutions contain, no matter what else is present, hydrogen ions and hydroxyl ions. In a neutral solution the respective concentrations of these two ions are equal. In an acid solution the hydrogen-ion concentration is in excess of the hydroxyl-ion concentration, while in an alkaline solution the reverse is true. These ideas of acidity, neutrality, and alkalinity are applicable to water suspensions and water extracts of soil.

THE EXPRESSION FOR SOIL REACTION

In this paper the degree of soil reaction refers to the numerical value of the hydrogen-ion concentration as determined by the hydrogen electrode. This value can also, with certain restrictions, be determined by the use of indicators. Gillespie (*14*)[3] found that there was a fairly

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[2] The writer desires to express his appreciation to Professors T. L. Lyon, J. A. Bizzell, and H. O. Buckman for helpful suggestions in doing this work and in preparing the thesis.

[3] Reference is made by number (italic) to "Literature cited," p. 120-123.

close agreement in the values obtained by the use of the electrometric and the colorimetric methods. The method of expressing this value by the symbol P_H and some number is well known. Extensive bibliographies relative to hydrogen-ion concentration are given by Schmidt and Hoagland (*40*) and by Clark (*7*).

ADSORPTION AND ABSORPTION

By adsorption is meant a combination of chemical substances such that the resulting product is neither a definite chemical compound nor a homogeneous mixture. When CO_2 combines with CaO the product at equilibrium is a definite chemical compound. When HCl is added to water the product is a homogeneous substance. When this acid mixes with water there are no such surface phenomena as are found when a solid phase is present and absorption is used as the descriptive term. With adsorption are associated the ideas of surface and heterogeneity. When varying quantities of $Ca(OH)_2$ are added to soil in the presence of water a series of definite chemical compounds may be formed even though their presence would be difficult to prove or disprove. That the amount of $Ca(OH)_2$ taken up by a given quantity of soil is governed by various factors, one of which is the amount of clay, indicating a large extent of surface, was shown in a former publication (*44*). That the combination of soil and $Ca(OH)_2$ when mixed in various amounts is neither a homogeneous mixture nor probably a definite chemical compound will be evident from the data to be presented. No attempt has been made to determine chemical equilibrium in this investigation; it is very probable, however, that definite chemical compounds form at equilibrium. Since there are surface phenomena and heterogeneity, the term adsorption rather than absorption is used, although some writers, notably Lyon and Buckman (*31*, p. 263) prefer the latter term.

HYDROGEN ELECTRODE IN USE WITH SOIL

A large amount of work has been done and many papers published on the subject of soil acidity. McIntire (*33*), Fisher (*13*), Ames and Schollenberger (*2*), as well as others, have discussed this subject fully and given extensive citations to literature. A study of the data presented by different investigators will show that the results obtained are dependent upon the methods used in making the determinations. The results from one method are therefore comparable with those of another only in a general way. The hydrogen electrode, as a means of measuring the hydrogen-ion concentration in soil, has not yet been used as extensively as some of the other devices. It has been employed to a limited extent in soil investigations by Gillespie (*14*), Plummer (*37*), Knight (*26*), Sharp and Hoagland (*41*, *23*), Swanson et al. (*44*), and others.

To indicate qualitatively the hydrogen-ion concentration in a soil suspension or a soil extract, the hydrogen electrode offers a comparatively simple and rapid procedure, and the results are probably more accurate than those obtained by any other method. Electrometric titration as a means of determining the amount of acid or alkali required to titrate to the neutral point, or to change the P_H present to that of any other desired P_H can be used rapidly and successfully with many substances

for which indicators are unsuited. With soils electrometric titration has not come into extensive use because of certain inherent difficulties that have been pointed out by those who have used the method (*26, 41*). Some of these will be discussed later.

RELATION OF INTENSITY AND QUANTITY OF ACIDITY

The P_H value obtained by the hydrogen electrode on a soil suspension gives a measure of the actual amount of hydrogen ions present under the conditions of the experiment. This is often designated as "intensity of acidity" (*14*) and is very different from the total quantity of hydrogen ions which may be produced by the gradual introduction of hydroxyl ions. This point may be illustrated with the following example: A certain solution gives a reaction equivalent to P_H 5. This means that there is present 0.00001 gm. hydrogen ions per liter of solution. Suppose that in this case it takes five cc. of a 0.04N hydroxid to bring 1,000 cc. of this solution to P_H 7. Five cc. of 0.04N hydroxid solution contain enough hydroxyl ions to react with 0.0002 gm. hydrogen ions. In other words, if a liter is titrated, the figure which represents the total acidity is 20 times greater than the figure which represents the intensity of acidity. If it takes 5 cc. of 0.04N hydroxid to change 100 cc. from P_H 5 to P_H 7, the total acidity is 200 times greater than the figure which represents the intensity.

DIFFICULTY IN THE USE OF THE HYDROGEN ELECTRODE WITH SOIL

In speaking of the electrometric titration of soil with standard $Ca(OH)_2$, Sharp and Hoagland remark (*41*): "Such a method is logically adapted to obtain the information necessary for the proper adjustment of the soil reaction by the addition of lime. There are, however, certain difficulties met with in its application to soils. One of the chief difficulties is due to the relative insolubility of the acid-forming constituents of soil which prevent a rapid attainment of equilibrium." Data given by these investigators show that the time necessary to attain equilibrium varied from 3 to 110 hours. This time factor and other difficulties are also discussed by Knight (*26*). That the direct electrometric titration of a soil suspension is a tedious and difficult operation is known to anyone who has tried the method. The direct titration was used in a former investigation (*44*), and it was noted that if observations were made soon after the introduction of the $Ca(OH)_2$ solution into a soil suspension it would usually be found that the voltage reading was greatly increased. If readings were taken at, say, five-minute or longer intervals, it would be found that the reading decreased, or the H-ion concentration gradually increased. This means that H ions are produced by more of the acid-forming constitutents going into solution. This change may continue until a P_H value of, say, 6 or 5 is obtained, showing that if neutrality is desired more hydroxid must be added. As soon as this is added the voltage reading again suddenly goes up, numerically, probably beyond the equivalent of P_H 7. This does not necessarily mean that too much or even enough hydroxid has been added. The readings will again gradually decrease, showing that hydroxid must again be added if neutrality is to be attained. It is necessary to repeat this process several times, until equilibrium is established at P_H 7, or any other

desired figure. Furthermore, the nearer the value approaches the neutral point the longer time is required to attain equilibrium. This is particularly true with clay and silt soils.

The fact that on soils a P_H value may be obtained which indicates a larger H-ion concentration than hydroxyl-ion concentration means that the acid-producing substance is soluble and ionized, even if the degree of such solubility and ionization is small. Regardless of whether it is large or small, the gradual introduction of OH ions causes a change such that more hydrogen ions are produced. The slowness of this change is the fundamental difficulty in using the hydrogen electrode as the basis of a quantitative method for soil. Sometimes the complicated and expensive apparatus necessary is cited as an objection, but this is no more valid for soil than for the large number of other substances on which electrometric measurements are made accurately and rapidly.

THE PROBLEM INVESTIGATED

The experiments presented in this paper were prompted by a desire to overcome some of the difficulties encountered in the use of the hydrogen electrode for the quantitative measurements involved in the adjustment of the hydrogen-ion concentration of a soil suspension to any other desired concentration. At the same time, it was desired to study some of the phenomena associated with the adsorption of calcium when added to the soil in the form of a $Ca(OH)_2$ solution. The time of the investigator is an important factor. To eliminate the time factor as an objection to the use of the electrometric method for soil, it is necessary to devise apparatus and methods which require the minimum amount of continous attention.

For work on soil acidity neutral salts have been much used. A neutral salt, such as KCl, also forms a part of the electrical connection between the electrode vessel and calomel cell. For these reasons this salt was included in the work here presented. The relative solubility of the acid-producing substance was studied by making measurements on both suspensions and extracts of soils. Calcium was for the most part added in the form of a $Ca(OH)_2$ solution. In some experiments precipitated $CaCO_3$ was used in addition to the $Ca(OH)_2$.

METHODS OF EXPERIMENTATION

SPECIAL APPARATUS

The potentiometer system, essentially as outlined by Hildebrand (*21*) was used in this investigation. The apparatus consists of the following principal pieces: One Weston direct-reading laboratory standard voltmeter, No. 5; one Kohlrausch slide-wire bridge, one Leeds and Northrup No. 2500 type R galvanometer with lamp and scale, Edison storage batteries, and other necessary accessories. The saturated potassium chlorid-calomel cell was chosen as best suited for soil work. Fales and Mudge (*12*) have shown that this type is the most reliable.

An apparatus was devised by which it was possible to have six electrodes in operation at the same time, so arranged as to require very little continuous attention. The position of these electrodes with reference to one another and the wiring arrangement are shown in figure 1. A side view of one of the combinations of hydrogen electrode and calomel

cell is shown in figure 2. The frame holding the six electrode vessels is supported by an iron rod passing through a hole over the center of gravity. The electrode vessels can be shaken continuously by means of the apparatus represented in figure 3. The shaking apparatus is operated by an electric motor producing about 120 agitations per minute. The hydrogen electrode, shown in figure 4, is constructed on the same plan as Hildebrand's (*21*). The hydrogen was made electro-

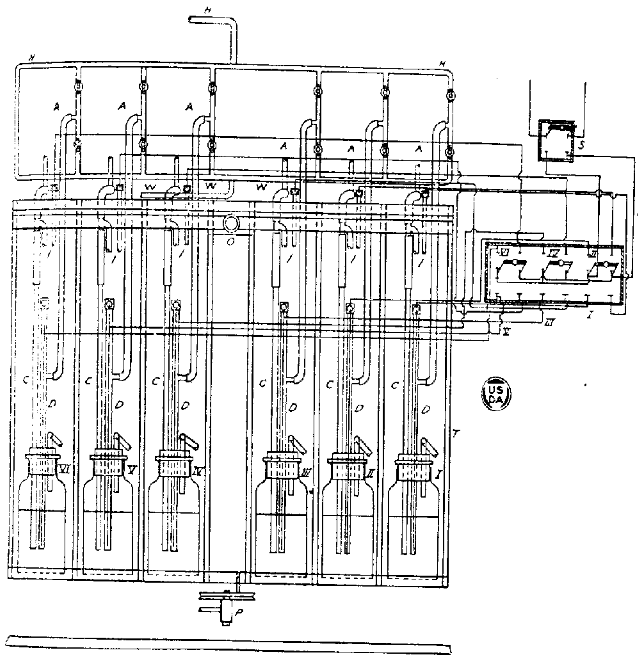

FIG. 1.—Diagram illustrating the arrangement of the electrode vessels on a supporting frame which is rotated from below by means of a pulley, thus giving the desired amount of shaking. Each pair, comprising electrode vessel and calomel cell, is wired independently and is connected to the potentiometer by means of its own switch, shown at the right, through the main switch S. The individual switches are numbered with Roman numerals, and each corresponding bottle used as electrode vessel is numbered with the same numeral. The hydrogen enters at H and is distributed to the six electrode vessels. The rate of flow to each is controlled by an ordinary glass stopcock. Water for washing the electrodes is admitted from below at W and enters the electrode through the same tube as the hydrogen.

lytically and obtained compressed in iron cylinders. It was purified in a train of saturated solution of $HgCl_2$, alkaline pyrogallic acid, alkaline permanganate and distilled water.

SOILS AND OTHER MATERIALS USED

The general plan was to make an intensive study on one soil and then extend certain phases to other soils and other materials. Oswego silt loam was selected for the more extended study. The sample was taken in southeastern Kansas, where acid soils are more common than in the rest of the State. It contained a small amount of calcium and was moderately acid. A characteristic feature of this type of soil is the compact,

heavy subsoil. Soil samples, representing different types taken during the soil survey in various parts of the State, were available for certain phases of the work. The soils were ground in a ball mill to pass a 100-

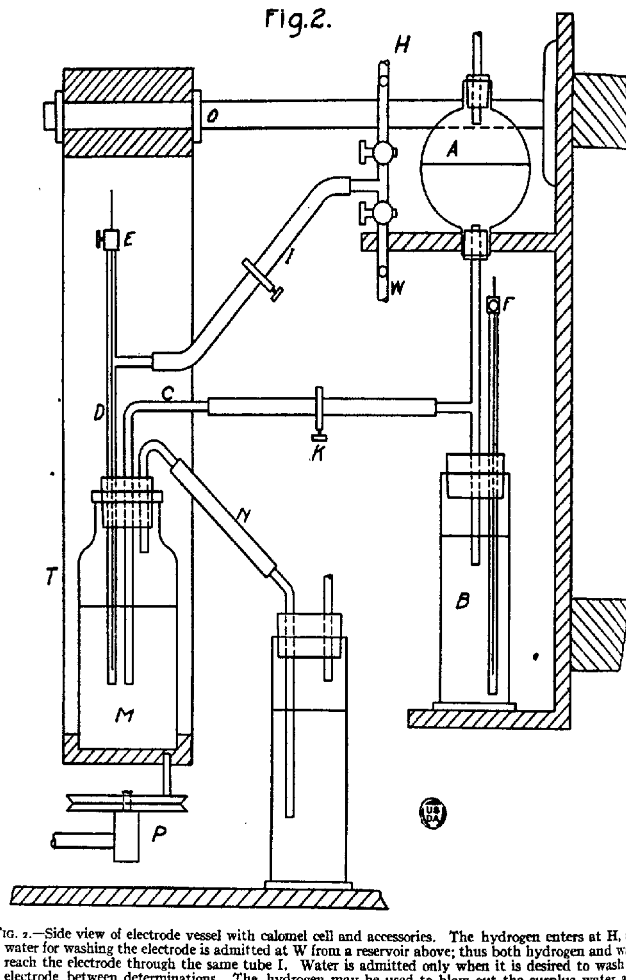

FIG. 2.—Side view of electrode vessel with calomel cell and accessories. The hydrogen enters at H, and water for washing the electrode is admitted at W from a reservoir above; thus both hydrogen and water reach the electrode through the same tube I. Water is admitted only when it is desired to wash the electrode between determinations. The hydrogen may be used to blow out the surplus water after washing. The rate of hydrogen flow is controlled by the stopcock in the tube H. A is the reservoir for the potassium chloride solution, connecting directly with the calomel cell B below and the electrode vessel M through the capillary tube C. The stopcock K can be an ungreased ordinary glass stopcock, or a Mohr's pinchcock may be used on a rubber tube. N, outlet tube for spent hydrogen, which passes through water in the bottle below. Instead of this arrangement a Bunsen valve may be used. E, wire from the hydrogen electrode. F, wire from the calomel cell. The pairs of wire go to the individual switches shown in Figure 1. O, iron rod which supports the frame holding the six electrode vessels.

mesh sieve. As all were free from fine gravel and stones this grinding did not alter the texture. Besides these soils there were used ignited soil, acid-treated soil, leached soil, and fuller's earth.

CALCIUM HYDROXID AND WATER FOR DILUTION

The calcium hydroxid solution was made by adding distilled water to an excess of calcium oxid and allowing to settle. The titration value and calcium in a measured portion had to be determined frequently, as it was found that the concentration would change slightly on standing in contact with an excess of solid $Ca(OH)_2$. For some of the work, solutions of definite $Ca(OH)_2$ concentrations were made. To make these was time-consuming; furthermore, it was impossible in practice to maintain a constant concentration for any considerable period of time. A more satisfactory procedure was to use a saturated $Ca(OH)_2$ solution of known strength, and to adjust the relative proportions of soil, $Ca(OH)_2$ solution and water in such a way that a definite number of cc. of the $Ca(OH)_2$ solution would represent the number of milligrams of calcium desired per 10 grams of soil.

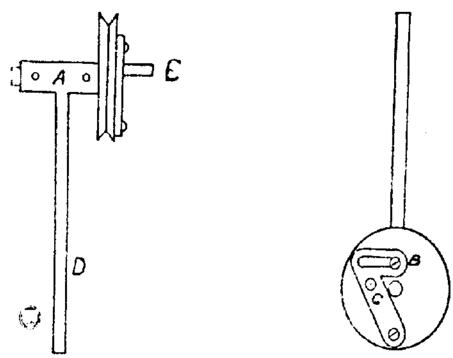

FIG. 3.—Apparatus for shaking the support for the electrode vessels. Red D is fastened in an ordinary laboratory clamp holder. The radius of the circle described by the crank pin C can be changed by adjusting the screw at B. By this arrangement and by altering the speed of the motor, the electrode vessels can be subjected to any desired degree of shaking.

When ordinary distilled water was used, it was purified by bubbling air free of CO_2 through it for about five hours. At the end of this time 100 cc. would give a distinct color with 1 drop of 0.05N NaOH, using phenolphthalein as an indicator. For most of the work water made in a conductivity still was used.

RELATIVE AMOUNTS OF SOIL, LIQUID, AND CALCIUM

On the basis of some preliminary work, and also the work of Sharp and Hoagland (*41*), Plummer (*37*), and others, it was decided to use soil and liquid in a ratio of 1:10. The amount of soil and other materials used in the different determinations were such that the final data are on the basis of 10 grams of soil. A saturated solution of $Ca(OH)_2$ has a normality of about 0.042, but for convenience in final calculations the dilutions of the $Ca(OH)_2$ solution were calculated to the basis of 0.04N, or a definite fraction of this normality. Five cc. of 0.04N $Ca(OH)_2$ solution contain 4 mgm. of calcium, or the equivalent of 10 mgm. $CaCO_3$. This gives a ratio of 1:1,000 when 10 grams of soil are used, or, figuring the weight of soil 7 inches deep at 2,000,000 pounds, the equivalent of 1 ton per acre. Accordingly each cc. of 0.04N $Ca(OH)_2$ represents 400 pounds of $CaCO_3$ per acre. In a few of the experiments, where calcium hydroxid solutions of definite concentrations were used, there is a variation from this ratio. In such instances the exact amount of calcinm added per 10 grams of soil is given.

PREPARATION OF THE SOIL SUSPENSION

Soil, water, $Ca(OH)_2$ solution, or other chemical, two or more as the particular experiment called for, were placed in 500 cc. wide-mouth bottles and closed with rubber stoppers. These were then placed on a shaking machine which had a 2-inch forward and back motion at the rate of about 90 vibrations per minute. From preliminary experiments it was found that it was best to leave the soil in contact with the $Ca(OH)_2$ for about 24 hours. Experiments in which contact existed for 48, 72, and 96 hours indicated that slight chemical changes took place after 24 hours, but so small in fact as not to interfere with the main purpose of these experiments. The usual plan was to prepare the mixtures in the afternoon, shake for an hour, let stand over night and then shake for a while the next morning. The suspensions were then transferred to 250 cc. wide-mouth bottles used as electrode vessels, and the electrometric measurements made the same day. As six of these measurements were carried on simultaneously, 12 or 18 determinations were a convenient day's work with those suspensions or extracts which attained equilibrium in the usual time.

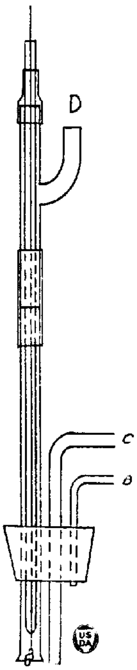

FIG. 4.—Hydrogen electrode supported in rubber stopper which fits the bottle used as electrode vessel. C, capillary glass tube making connection with the saturated potassium chloride calomel cell. B, glass tube through which excess gas may escape. The hydrogen enters at D.

PREPARATION OF SOIL EXTRACTS

For the extracts 20 gm. of soil and 200 cc. of $Ca(OH)_2$ were generally used. These quantities were sufficient to produce 100 cc. of material for the titrations and calcium determinations and at least 50 cc. for the electrometric measurements. After shaking in the same manner as for making the suspensions the soil was allowed to settle. When the quantity of electrolytes present were sufficient to cause coagulation, a clear solution could be obtained by pipetting off the supernatant liquid. In other cases the contents of the bottles were transferred to 500 cc. bottles and centrifugalized for about five minutes. The centrifugal force attained was about 1,300 times gravity. A perfectly clear solution was not always obtained by this method, as some colloidal clay frequently remained in suspension. The opalescence was approximately that obtained by long-time settling of clay in water. This did not interfere with the titrations, and usually did not interfere with the calcium determinations. Some calcium silicate may have been present in colloidal suspension and may account for a small part of the calcium obtained in some extracts. The colloidal matter seemed to affect the electrometric measurements, making them more uncertain and reducing the number of times an electrode could be used before replatinizing.

TITRATION AND CALCIUM DETERMINATION

The titrations were made by means of 0.05N HCl and 0.05N NaOH, using phenolphthalein as an indicator. The extracts were usually boiled before titrating. The maximum difference in titrating 100 cc.

of boiled or unboiled extracts was 0.2 to 0.3 cc. of the standard solution. These figures are within the limits of the error of any data used as a basis for conclusions in the present investigation. The portion used for titration was also used for the determination of calcium. The extracts were made acid with HCl and the calcium was precipitated as oxalate in the presence of NH_4Cl and sodium acetate. The oxalate was filtered on asbestos, dissolved in H_2SO_4 and titrated with 0.05N $KMnO_4$.

MAKING THE ELECTROMETRIC MEASUREMENTS

Before using, the electrodes were tested by making a blank determination on a standard acetate solution (*4, 35*). This blank determination was made every day. Experience showed that if the electrodes were carefully washed after each determination they could be used three or four times before they needed to be replatinized. The hydrogen was bubbled through the suspensions or extracts contained in the electrode vessels, which were shaken continuously during the measurements. Readings were taken at such intervals as were found necessary, and continued till they remained constant, within 1 millivolt, for five minutes or more. Most soil suspensions or extracts did not come to an apparent equilibrium in much less than an hour, and many required a longer time. Extracts or suspensions, the reaction of which is near P_H 7 come to equilibrium much more slowly than those of a higher or lower P_H. This was particularly true if $CaCO_3$ was present. In some such cases the material required as much as five or six hours to come to equilibrium. The tables of Schmidt and Hoagland (*40*) were used for calculating the P_H values corresponding to the voltmeter reading, the necessary correction for the saturated calomel cell being made.

EXPERIMENTAL RESULTS

GROUP A.—INFLUENCE OF CALCIUM HYDROXID, CALCIUM CARBONATE, POTASSIUM CHLORID, HYDROCHLORIC ACID, AND OXALIC ACID, SINGLY OR IN COMBINATION, UPON P_H OF SUSPENSIONS AND EXTRACTS OF NATURAL SOIL; ALSO UPON THE TITRATION AND CALCIUM CONTENT OF THE EXTRACTS

EXPERIMENT 1.—SOIL+WATER

It has been shown by several investigators (*23, 37, 41*) that the reaction obtained on a soil suspension in water is different from that obtained on a filtered extract. This difference is due to the relative insolubility of the acid-forming substance. In Table I are found the P_H values obtained on four soils, together with the titration values on 100 cc. extract and the amount of water-soluble calcium. The extracts of these four soils came to equilibrium very slowly. These extracts were not boiled before titrating, and so contain the maximum amount of CO_2 likely to be present in such extracts. The amount of calcium obtained is small. This was to be expected, since the total calcium content of these soils is low.

TABLE I.—P_H *on water suspensions and extracts of soils, titrations, and calcium content of extracts*

Soil type.	Suspension.	Extracts.	0.05N NaOH.	Calcium in extract.
	P_H	P_H	*Cc.*	*Mgm.*
Neosho silt loam	6.48	8.54	0.45	1.0
Oswego silt loam	5.66	8.50	.40	1.3
Bates very fine sandy loam	4.82	8.50	.50	.7
Bates loam	7.56	8.61	.50	1.9

Rice and Osugi (*39*) found that the suspensions of many soils would invert cane sugar, while the extracts of such soils had little or no power. Soils containing calcium in equilibrium with HCO_3 and CO_2 have an alkaline reaction (*23*).

In some cases, in connection with experiments reported in this paper, titrations were made on the water extracts used for the electrometric measurements. In such cases the hydrogen removed the CO_2, and one drop of the 0.05N NaOH would produce a color with the indicator. This means that the titrable acidity of the extracts in Table I was due to carbonic acid. The maximum error of titration in any experiment due to the presence of CO_2 was therefore small, and when the CO_2 was removed by boiling or by bubbling hydrogen it was nil. The slowness of attaining equilibrium when $CaCO_3$ was present was evidently due to the slow decomposition of this substance under the conditions of the experiment.

EXPERIMENT 2.—SOIL + WATER + POTASSIUM CHLORID

The same soils were used as in Experiment 1, but in making the suspensions and the extracts enough of a 3N KCl solution was added to make the liquid in contact with the soil 0.5N KCl. Preliminary experiments showed that it made no material difference at what point in the preparation that KCl was added. In all of the experiments where this salt was used the amount was such as to make the concentration 0.5N. The results obtained are presented in Table II.

TABLE II.—P_H *on suspensions and extracts of soils made with a solution of KCl and the calcium content of the extract*

Soil type.	Suspensions.	Extracts.	Calcium in extract.
	P_H	P_H	*Mgm.*
Neosho silt loam	5.83	7.29	8.0
Oswego silt loam	5.02	6.61	14.1
Bates very fine sandy loam	4.51	4.95	7.0
Bates loam	6.48	6.97	21.5

The presence of the neutral salt, KCl, increases the hydrogen-ion concentration both in the suspensions and in the extracts. This would indicate that the acid-forming substance is more soluble in a KCl solution than in water. Sharp and Hoagland (*41*) found that other neutral

salts such as NaCl and $BaCl_2$ as well as KCl increased the hydrogen-ion concentration of certain soil suspensions. What happens may be pictured as follows:

$$KCl \rightleftarrows K^+ + Cl^-$$
$$HOH \rightleftarrows OH^- + H^+$$

The increase in hydrogen-ion concentration is due to the greater adsorptive capacity of soil for the K^+ and OH^- ions. According to Parker (*36*) molecular adsorption of KOH may also take place.

It will be shown in a subsequent experiment that the amount of calcium made soluble in a 0.5N KCl solution is very nearly the same as in 0.5N HCl solution. The above equations show that it is simply a reaction of calcium with chlorinions whether the solution is made with HCl or KCl.

EXPERIMENT 3.—SOIL + CALCIUM CARBONATE [4]

Precipitated $CaCO_3$ was added in definite amounts to 10 gm. of soil. Two groups of mixtures were prepared. One group was placed in 125-cc. wide-mouthed glass-stoppered bottles, sealed, and let stand for 6 weeks, with occasional shaking. On this group the P_H values were determined on the suspensions only. The other group was given the usual 24 hours contact and the P_H values were determined on both the suspensions and the extracts. The results are presented in Table III.

TABLE III.—*P_H on water suspensions and extracts of soils to which $CaCO_3$ had been added*

Calcium added.	Oswego silt loam.			Bates very fine sandy loam.		
	6 weeks.	24 hours.		6 weeks.	24 hours.	
	Suspension.	Suspension.	Extract.	Suspension.	Suspension.	Extract.
Mgm.	P_H	P_H	P_H	P_H	P_H	P_H
2.5	7.46	6.00	6.31	7.79	5.66	6.24
5.0	7.93	7.05	6.64	8.10	6.30	7.59
10.0	8.10	7.83	8.34	8.10	7.79	8.23
20.0	8.13	7.93	8.42	8.40	8.30	8.10
40.0	8.37	8.13	8.93	8.40	8.37	8.91

Calcium added in the form of $CaCO_3$ will change the hydrogen-ion concentration of a soil suspension, and the amount of change up to a certain point is proportional to the quantity of $CaCO_3$ added. In a supplementary experiment it was found that the P_H for suspensions prepared from soils to which increasing quantities of $CaCO_3$ were added would approach a maximum of about 8.50, and remain at this figure regardless of the quantity of $CaCO_3$ added, up to 20 tons equivalent per acre. When the same amount of $CaCO_3$ is added to soil, a long-time contact produces a greater hydroxyl-ion concentration than a short time. The acid-producing substance in soil liberates its hydrogen ions very slowly. It has been shown by Hagar (*15*) and McIntire (*32*, p. 41–45,) that $CaCO_3$ undergoes profound changes in soil.

[4] As water was used in all of the experiments in such amounts as to make the proportion of soil and liquid 1:10, the presence of this substance is to be understood.

EXPERIMENT 4.—SOIL+CALCIUM CARBONATE+POTASSIUM CHLORID

In this experiment KCl was added to the soil in addition to the $CaCO_3$, and the time of contact was 24 hours. The results for P_H titrations and calcium are presented in Table IV.

TABLE IV.—*P_H on suspensions and extracts of soil+$CaCO_3$ made with a solution of KCl; also the titration and calcium content of the extracts*

Calcium added.	Oswego silt loam.				Bates very fine sandy loam.			
	Suspension.	Extract.	0.05 N HCl.	Ca in extract.	Suspension.	Extract.	0.05 N HCl.	Ca in extract.
Mgm.	P_H	P_H	*Cc.*	*Mgm.*	P_H	P_H	*Cc.*	*Mgm.*
2.5	5.6	7.3	0.0	14.1	5.2	5.1	−0.1	8.2
5.0	6.0	7.6	−.1	17.7	5.6	6.3	−.1	9.4
10.0	7.1	8.3	.0	19.8	7.2	8.4	.0	13.6
20.0	7.5	8.4	.4	20.4	7.8	8.4	.4	18.7
40.0	7.6	8.5	.4	24.4	8.0	8.4	.5	19.6

When salts like KCl, NaCl and $CaCl_2$, each composed of a strong base and a strong acid, are added to soil the H-ion concentration of the soil suspension is increased. $CaCO_3$ is a salt of a strong base and a weak acid. When carbonates were added to soil (Experiment 13) the H-ion concentration of the suspension was decreased. In Experiment IV the KCl increased the hydrogen-ion concentration, even in the presence of $CaCO_3$. The calcium in the extract was dissolved by KCl partly from the soil and partly from the added $CaCO_3$, but only a part of the added $CaCO_3$ was dissolved. When 40 mgm. of calcium were added in the form of $CaCO_3$, the amount obtained in solution was only about 10 mgm. more than when 2.5 mgm. were added.

The titrations with 0.05N HCl were made on the same solutions in which the calcium was determined. Each cc. of this standard HCl solution is stoichometrically equivalent to 1 milligram of calcium as a carbonate or as a hydroxid. The small values of the titer figures show that very little calcium was present in such forms. The KCl furnishes the conditions essential for changing the calcium to $CaCl_2$ and it is probable that the calcium was present in the form of a neutral salt. The high hydroxyl-ion concentrations obtained with the larger amounts of $CaCO_3$ were due to the presence of the ions HCO_3, CO_3, and Ca, which are ions of a weak acid and a strong base.

EXPERIMENT 5.—SOIL+CALCIUM HYDROXID

In this and the following experiments Oswego silt loam was used unless a statement to the contrary is made. The $Ca(OH)_2$ solution was added to the soil in increasing amounts, beginning with 2.5 mgm. and running up to 80 mgm. of calcium equivalent for 10 gm. of soil. These amounts represent from one-third ton to 20 tons equivalent of $CaCO_3$ per acre. The results are given in Table V.

TABLE V.—*P_H on suspensions and extracts of soil + $Ca(OH)_2$, also titrations and calcium content of extract and calcium adsorbed by soil*

Calcium added.	Suspension.	Extract.	Titer 0.05N HCl.	Calcium in extract.	Calcium not adsorbed.	Calcium adsorbed.
Mgm.	P_H.	P.	*Cc.*	*Mgm.*	*Mgm.*	*Mgm.*
2.5	6.14	8.06	−0.1	2.4	0.0	2.5
5.0	7.08	8.20	−.1	2.3	.0	5.0
8.0	7.45	8.54	.0	2.0	−.3	8.0
12.0	7.90	8.57	.4	2.3	.0	12.0
16.0	8.13	8.88	.4	2.7	.4	15.6
20.0	8.71	8.91	.5	3.7	1.4	18.6
28.0	9.55	9.38	.6	4.0	1.7	26.3
36.0	10.46	10.23	.8	4.7	2.4	33.6
48.0	11.07	11.00	1.6	8.0	5.7	42.3
60.0	11.54	11.41	3.5	13.0	10.7	49.3
80.0	11.85	11.71	12.6	23.3	21.0	59.0

The figures for the smaller amounts of calcium added are the averages of several determinations. The P_H values show that the hydrogen-ion concentrations were higher in the suspensions than in the extracts until more than 16 mgm. of calcium had been added. Beyond 16 mgm. of calcium the P_H values for suspensions and extracts were nearly equal. In these the OH-ion concentration was so large as to mask the influence of any substance dissolved from the soil. The P_H values became equal in the suspension and the extracts when the adsorption of calcium ceased to be practically complete. This is shown in what follows.

All of the extracts to which less than 16 mgm. of calcium were added contained nearly the same amounts of calcium. This calcium may be accounted for partly by the small amount of water-soluble calcium in the soil, and partly from the re-solution of adsorbed calcium. The water-soluble calcium from the soil was 1.3 mgm. In the presence of $Ca(OH)_2$ this amount would be less. When $Ca(OH)_2$ comes in contact with soil in such a water suspension as was used in this experiment it probably forms an adsorption compound. This compound would be to some extent soluble in water (*26*) and would account for a larger part of the calcium in those extracts in which the adsorption was practically complete. Part of the calcium may have been present in a colloidal suspension, however, as shown by titration results; very little, if any, could have been present as a carbonate.

The average amount of calcium found in the extracts, when 16 or less mgm. were added as $Ca(OH)_2$, was 2.3 mgm. The mgm. of the adsorbed calcium were obtained by subtracting 2.3 from the subsequent figures in the column. According to this calculation, adsorption can be considered complete until 16 or more mgm. of calcium were added and comparatively little remained unadsorbed until more than 36 mgm. were added. This shows the large adsorptive capacity of this soil for calcium when added in the form of $Ca(OH)_2$. Since 4 mgm. represent the equivalent of 1 ton of $CaCO_3$ per acre 7 inches deep, this soil requires the equivalent of between 4 and 5 tons of CaCO per acre to produce a P_H value in the suspension corresponding to the color change of phenolphthalein. (See fig. 6.)

EXPERIMENT 6.—SOIL+CALCIUM HYDROXID+POTASSIUM CHLORID

This experiment was performed like Experiment 5, with the exception that KCl was used in addition to the $Ca(OH)_2$. The data obtained are presented in Table VI. In comparison with those in Table V, the data show clearly that the hydrogen-ion concentration was considerably increased by KCl, even when large amounts of $Ca(OH)_2$ were added. In the presence of KCl more of the hydrogen ions are liberated from the acid-forming substances, and more $Ca(OH)_2$ is required for neutralization. The absolute neutral point was passed when between 2 and 3 tons equivalent of $CaCO_3$ per acre were added in the form of $Ca(OH)_2$. The figures for the P_H values in Tables V and VI present some variations not easily explained, probably due to some disturbing factors not understood.

TABLE VI.—*P_H on suspensions and extracts of soil+$Ca(OH)_2$+KCl, also titrations and calcium content of extract, and calcium adsorbed by soil*

Calcium added.	Suspension.	Extract.	Titer 0.05N HCl.	Calcium in extract.	Calcium not adsorbed.	Calcium adsorbed.
Mgm.	P_H.	P_H.	*Cc.*	*Mgm.*	*Mgm.*	*Mgm.*
0.0	5.02	6.61	−0.1	14.0	0.0	0.0
2.5	5.50	6.70	−.1	15.5	1.5	1.0
5.0	5.70	....	−.1	16.1	2.1	3.9
8.0	6.46	6.71	−.1	19.3	5.3	2.7
12.0	7.22	7.25	−.1	21.1	7.1	4.9
16.0	7.93	7.45	−.2	21.3	7.3	8.7
20.0	8.50	7.76	.0	23.5	9.5	10.5
28.0	9.32	8.10	.0	26.5	12.5	15.5
36.0	10.13	....	.5	29.6	15.6	20.4
48.0	11.00	10.94	1.0	35.0	21.0	27.0
60.0	11.41	11.41	1.4	41.2	27.2	32.8

The calcium in the extract came from that dissolved from the soil by KCl and also from the added $Ca(OH)_2$. The calcium not adsorbed was obtained by subtracting 14, the figure obtained when no $Ca(OH)_2$ was added, from each subsequent figure. The figures so calculated for unadsorbed calcium are considerably larger than the corresponding ones in Table V. When KCl is present part of the soil's capacity for adsorbing the base is satisfied, and less calcium is adsorbed. A little over half as much calcium was adsorbed in Experiment 6 as in Experiment 5. Even this amount of adsorption is large when the large excess of KCl is considered, and it shows the great capacity of the soil for adsorbing calcium. (See fig. 6.)

EXPERIMENT 7.—SOIL+CALCIUM HYDROXID+CALCIUM CARBONATE

The amounts of precipitated $CaCO_3$ equivalent to the calcium in the different portions of $Ca(OH)_2$ used in Experiment 5 were mixed with the various portions of dry soil. The rest of the experiment followed the method of No. 5. The data obtained are presented in Table VII. (See fig. 5.)

ABLE VII.—*P_H on suspensions and extracts of soil+$CaCO_3$+$Ca(OH_2)$, also titrations and calcium content of extract and calcium adsorbed by soil*

Ca added in $Ca(OH)_2$.	Ca added in $CaCO_3$.	Suspension.	Extract.	0.05N HCl.	Calcium in extract.	Calcium not adsorbed.	Calcium adsorbed.
Mgm.	*Mgm.*	P_H.	P_H.	*Cc.*	*Mgm.*	*Mgm.*	*Mgm.*
2.5	2.5	7.1	7.7	−0.2	2.4	0.0	2.5
5	5	7.6	8.0	−.2	2.4	.0	5.0
8	8	7.73	8.4	.2	2.4	.0	8.0
2	12	7.96	8.54	.2	2.4	.0	12.0
6	16	8.27	8.57	.4	2.4	.0	16.0
0	20	8.81	8.67	1.2	2.4	.0	20.0
8	28	9.69	9.15	1.4	3.0	.6	27.4
6	36	10.46	10.43	1.5	4.6	2.2	33.8
8	48	11.38	11.14	4.1	8.4	6.0	42.0
0	60	11.55	11.53	10.4	14.3	11.9	48.1
0	80	11.88	11.85	20.3	25.6	23.2	56.8

The influence of the smaller quantities of $CaCO_3$ added was apparent n the greater hydroxyl-ion concentration produced with the smaller additions of $Ca(OH)_2$ solutions. Where the larger portions of $Ca(OH)_2$ were added, the influence of the equivalent amounts of $CaCO_3$ on the P_H values was nil. Here the excess of the hydroxyl-ions was so large as to mask completely the influence of the HCO_3 and CO_3 ions. The iter figures show that a larger amount of calcium was present as $Ca(OH)_2$ r $CaH_2(CO_3)_2$ than in Experiment 5, but the amounts of unadsorbed alcium in the extracts were the same. The figures for the adsorption f calcium were based on the amounts added in $Ca(OH)_2$. According o this method of calculation as much calcium was adsorbed from $a(OH)_2$ when $CaCO_3$ was present as when it was absent. It should be emembered that in the 24-hours contact, equilibrium between soil and aCO_3 had probably not been reached.

EXPERIMENT 8.—SOIL+CALCIUM HYDROXID+CALCIUM CARBONATE+POTASSIUM CHLORID

This experiment was performed in all respects like No. 7, except that Cl was employed in the usual concentration. The data obtained are iven in Table VIII. (See fig. 5.)

ABLE VIII.—*P_H on suspensions and extracts of soil+$CaCO_3$+$Ca(OH)_2$+KCl, also titrations and calcium content of extracts and calcium adsorbed by soil*

Calcium added in $Ca(OH)_2$.	Calcium added in $CaCO_3$.	Suspension.	Extract.	0.05N HCl.	Calcium in extract.	Calcium not adsorbed.	Calcium adsorbed.
Mgm.	*Mgm.*	P_H	P_H	*Cc.*	*Mgm.*	*Mgm.*	*Mgm.*
2.5	2.5	5.50	6.40	0.0	17.1	3.1	0.0
5	5	7.10	7.70	.0	19.2	5.2	.0
3	8	7.69	7.90	.1	21.3	7.3	.7
2	12	8.00	7.90	.2	21.6	7.6	4.4
5	16	8.10	7.96	.3	21.9	7.9	8.1
)	20	8.47	8.10	.5	23.8	9.8	10.2
3	28	9.38	8.28	.8	27.0	13.0	15.0
5	36	9.91	9.35	1.0	30.1	16.1	19.9
3	48	11.07	10.97	4.6	35.4	21.4	26.6
)	60	11.48	11.37	8.0	42.3	28.3	31.7

The presence of KCl was evident in the decreased number of OH ions produced by the addition of $Ca(OH)_2$. This was true for both suspensions and extracts, and similar to results obtained in preceding experiments in which KCl was used. The figures for calcium adsorption are very similar to those obtained in Experiment 6. In the short time contact of this experiment the total effect of KCl was not influenced by the presence of $CaCO_3$.

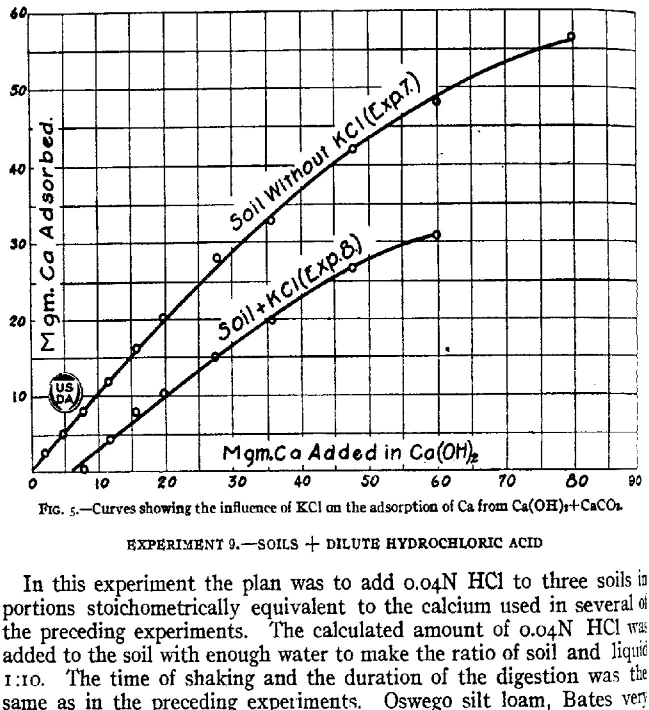

FIG. 5.—Curves showing the influence of KCl on the adsorption of Ca from $Ca(OH)_2+CaCO_3$.

EXPERIMENT 9.—SOILS + DILUTE HYDROCHLORIC ACID

In this experiment the plan was to add 0.04N HCl to three soils in portions stoichometrically equivalent to the calcium used in several of the preceding experiments. The calculated amount of 0.04N HCl was added to the soil with enough water to make the ratio of soil and liquid 1:10. The time of shaking and the duration of the digestion was the same as in the preceding experiments. Oswego silt loam, Bates very fine sandy loam, and Bates loam were used. The data obtained are presented in Table IX.

TABLE IX.—*P_H on suspensions and extracts of soil+HCl, also titrations and calcium content of the extracts*

HCl added.		Oswego silt loam.				Bates very fine sandy loam.				Bates loam.			
0.04N per 10 grams soil.	Ca equivalent.	Suspension.	Extract.	0.05N NaOH.	Calcium in extract.	Suspension.	Extract.	0.05N NaOH.	Calcium in extract.	Suspension.	Extract.	0.05N NaOH.	Calcium in extract.
Cc.	*Mgm.*	P_H.	P_H.	*Cc.*	*Mgm.*	P_H.	P_H.	*Cc.*	*Mgm.*	P_H.	P_H.	*Cc.*	*Mg*
3.12	2.5	4.78	5.19	0.4	1.9	4.14	5.93	0.5	1.5	6.00	5.36	0.2	2.
6.25	5.0	4.21	4.82	.4	3.1	3.70	4.12	.9	3.2	5.33	5.33	.2	4.
12.5	10.0	3.16	3.76	1.0	6.4	3.23	3.09	4.5	4.0	4.38	4.65	.3	6.
25.0	20.0	2.72	2.76	5.6	10.0	2.44	2.38	13.6	4.2	3.22	3.57	1.7	13.
50.0	40.0	2.18	2.14	23.2	12.4	2.04	1.91	32.9	4.6	2.42	2.48	12.4	20.

The P_H values on both suspensions and extracts showed an increase in hydrogen-ion concentration corresponding to the increased amounts of HCl added. Where the smaller amounts of HCl were added, the hydrogen-ion concentrations were greater in the suspensions than in the extracts. The same relationship between suspensions and extracts was found in the preceding experiments when small amounts of $Ca(OH)_2$ were added to soil. This was thought to be due to the relative insolubility of the acid-producing substance in soil. With HCl the added acid is soluble, and in the dilution used is completely ionized, yet the same differences in P_H were found between the suspensions and the extracts. This can be accounted for by the additive influence of the acid-forming substance in the soil suspension. The titration figures show that a portion of the HCl is neutralized or adsorbed by the soil, and the amount so used corresponds to the adsorptive capacity of the soil. The two soils which adsorbed the greatest amount of calcium (Experiment 19) also neutralized the greatest amount of HCl. Perhaps the greater portion, though not all, of the HCl was neutralized in dissolving calcium from the soil. The amount of calcium obtained in the extracts was proportional to the calcium content of the soil.

The main point shown in this experiment is that while the addition of small amounts of a highly ionized acid like HCl results in an increase in the hydrogen-ion concentration of the suspensions and the extracts, yet the influence of the acid-forming substance in the soil is also shown.

EXPERIMENT 10.—SOILS+OXALIC ACID

This experiment was performed in the same manner as No. 9, except that 0.04N oxalic acid was used. The data obtained are presented in Table X.

There was a notable difference in the P_H values obtained with the use of oxalic acid as compared with HCl. The addition of the three smaller portions of oxalic acid produced a decrease in the hydrogen-ion concentration, while the two larger portions caused an increase. This means that the addition of a small amount of oxalic acid produces an actual increase in the hydroxyl-ion concentration. The hydrogen-ion concentration produced by 50 cc. of 0.04N oxalic acid is not as great as that produced by the same amount of 0.04N HCl (Experiment 9). This is due simply to the smaller ionization of oxalic acid, and also to the formation of insoluble oxalates.

The titration figures show the expected gradual increase as the amount of acid added to the soil increased, and the figures for oxalic acid are larger than they are for HCl. Owing to the smaller solubility of calcium in oxalic acid, the amount of calcium obtained was less when oxalic acid was used than with HCl.

TABLE X.—P_H *on suspensions and extracts of soil + oxalic acid; also titrations and calcium content of the extracts*

$H_2C_2O_4$ added.		Oswego silt loam.				Bates very fine sandy loam.				Bates loam.			
0.04N per 10 gm. soil.	Ca equivalent.	Suspension.	Extract.	0.05N NaOH.	Calcium in extract.	Suspension.	Extract.	0.05N NaOH.	Calcium in extract.	Suspension.	Extract.	0.05N NaOH.	Calcium in extract.
Cc.	*Mgm.*	P_H.	P_H.	*Cc.*	*Mgm.*	P_H.	P_H.	*Cc.*	*Mgm.*	P_H.	P_H.	*Cc.*	*Mgm.*
3.12	2.5	4.95	5.80	1.5	0.8	5.39	8.00	1.8	0.7	7.95	8.37	0.4	3.6
3.25	5.0	5.43	7.83	2.9	1.2	......	7.93	4.1	.7	8.13	8.03	1.6	3.4
12.5	10.0	7.22	7.83	7.3	2.1	5.80	8.23	8.1	1.1	8.27	8.00	2.4	3.4
25.0	20.0	5.46	4.07	12.6	3.2	3.76	3.20	17.0	1.7	7.42	7.90	8.1	4.6
50.0	40.0	3.86	2.42	31.0	4.9	2.48	2.55	35.9	2.1	5.73	3.30	21.8	6.8

The increase in the hydroxyl-ion concentration with the smaller amounts of oxalic acid can be accounted for by the fact that a salt of a weak acid and a strong base has an alkaline reaction in a water solution. This is due to the formation of the highly ionized hydroxid of the base and the feebly ionized acid. The hydrogen ions and the hydroxyl ions come from the water. When oxalic acid is added to soil, oxalates are formed. If the quantity added to soil is small these oxalates are in excess, and there are more hydroxyl-ions than hydrogen ions. When larger amounts of oxalic acid are added the reverse condition occurs. The initial reaction and the calcium content of the soil appear to determine the amount of oxalic acid required to produce an excess of hydrogen ions. With Bates loam, a neutral soil with a relative higher calcium content, the excess of the hydroxyl ions persists for a larger amount of oxalic acid than is the case with the other two soils.

When NaOH is added to the extract a part is used in basic exchange with the oxalates and part to neutralize the free oxalic acid. Bates loam neutralized a larger portion of oxalic acid than the other two soils. This soil has more calcium, and therefore more insoluble calcium oxalate could be formed. This would appear to indicate that the quantity of an organic acid, such as oxalic, which a soil is able to neutralize is a measure of the potential alkalinity.

The effect of oxalic acid on soil, as shown in this experiment, explains a fact well known to agriculturists, namely, that barnyard manure reduces the acid condition of the soil. The acids which result from the decay of organic matter combine with the bases of the soil, forming salts of weak acids and strong bases. The effect of adding organic acids to soil deserves further study, particularly those which form soluble compounds, such as acetic acid.

GROUP B.—INFLUENCE OF CALCIUM HYDROXID AND POTASSIUM CHLORID ON THE P_H WHEN USED ON WASHED SOIL, IGNITED SOIL, ACID-TREATED SOIL, AND ACID-TREATED SAND, ALSO ON THE TITRATION AND CALCIUM CONTENT OF THE EXTRACT

EXPERIMENT 11.—WASHED SOIL + CALCIUM HYDROXID

In this experiment $Ca(OH)_2$ was added to washed soil in the same manner as in Experiment 5. In washing, part of the colloidal clay was removed. The method of washing was as follows: One kgm. of soil was

placed in a tall 8-liter bottle, and distilled CO_2-free water added until the bottle was nearly full. The bottle was then shaken for one hour, after which the soil was allowed to settle for one week. The supernatant liquid, still turbid with colloidal clay, was siphoned off without disturbing the soil in the bottom. The bottle was again filled with water and the process of shaking, settling, and removal of supernatant liquid repeated 12 times in as many weeks. As far as could be observed, the supernatant liquid was as turbid the last time it was siphoned off as it was the first time. The soil was transferred, using a small amount of water, to 1-gallon earthenware jars, and allowed to evaporate and dry completely at room temperature. Oswego silt loam, Bates very fine sandy loam, and Bates loam were thus treated. The resulting dry soil was very friable and loose. Determinations showed that only a small percentage of the soil had been removed as colloidal matter in the washing process.

In a preliminary trial $Ca(OH)_2$ was added in varying amounts to the three washed soils, but the differences in the data from the washed soils as compared with those from the untreated were relatively the same for the three soils. Table XI gives the results obtained on the Oswego silt loam.

TABLE XI.—*P_H of suspensions and extracts of washed soil + $Ca(OH)_2$; also titrations and calcium content of extracts, and calcium adsorbed from $Ca(OH)_2$*

Calcium added.	Suspension.	Extract.	0.05N. HCl.	Calcium in extract.	Calcium not adsorbed.	Calcium adsorbed.
Mgm.	P_H.	P_H.	*Cc.*	*Mgm.*	*Mgm.*	*Mgm.*
0.0	4.89	7.32	0.0	0.4	0.0	0.0
2.5	5.94	7.35	.1	.5	.1	2.4
5.0	6.07	8.03	.1	.7	.3	4.7
8.0	6.14	7.76	.2	1.1	.7	7.3
12.0	7.19	8.13	.3	1.4	1.0	11.0
16.0	7.62	8.47	.3	1.6	1.2	14.8
20.0	8.03	8.30	.2	1.7	1.3	18.7
28.0	8.94	8.34	.4	2.6	2.2	25.8
36.0	9.99	9.59	1.5	4.4	4.0	32.0
48.0	10.87	10.40	2.5	5.3	4.9	43.1
60.0	11.24	11.34	9.5	14.1	13.7	46.3
80.0	11.68	11.68	22.8	27.1	26.7	53.3

Comparing the figures of Table XI with those in Table V it will at once be apparent that the hydrogen-ion concentrations obtained, when different amounts of $Ca(OH)_2$ were added to the soil, were greater for the washed soil than for the untreated. This means that the washing process increased the solubility of the acid-producing substance. Since the acid-producing substance is slightly soluble, a small amount was removed in the washing process. However, this removal resulted in an increase, rather than a decrease, in the hydrogen-ion concentration of the suspensions and the extracts. This indicates a continuous and increasing solubility of the acid-producing substance. (See fig. 6.)

The differences in the figures for calcium adsorption obtained on the washed soil as compared with the untreated are practically within the limits of the experimental error. If there is any real difference, washing has decreased the adsorptive capacity of soil for calcium. This was probably due to the removal of colloidal clay.

EXPERIMENT 12.—IGNITED SOIL+CALCIUM HYDROXID

In this experiment $Ca(OH)_2$ was added to Oswego silt loam after it had been ignited. Weighed portions of soil as needed for the separate determinations were placed in flat-bottomed porcelain dishes and heated at 650° for five hours in an electric muffle having an automatic temperature control. After cooling, the ignited soil portions were transferred to bottles, and the subsequent treatment was the same as in Experiment 5. The loss on ignition as determined on one set of samples was nearly 5 per cent. The data obtained are presented in Table XII.

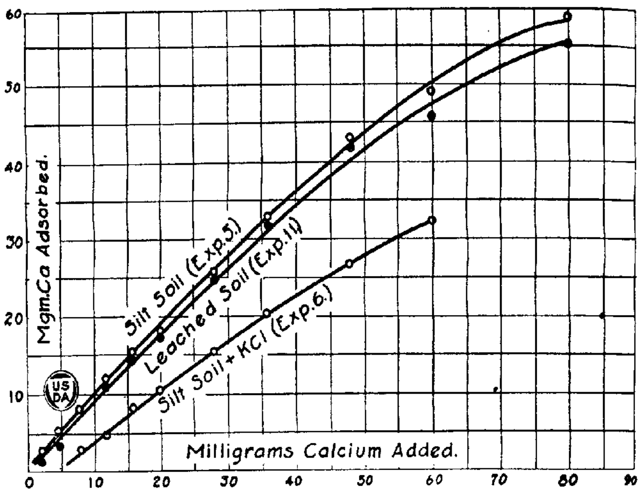

FIG. 6.—Curves showing the influence of KCl on the adsorption of calcium from $Ca(OH)_2$.

TABLE XII.—*P_H of suspensions and extracts of ignited soil+$Ca(OH)_2$, titrations and calcium content of extracts, and calcium adsorbed from $Ca(OH)_2$*

Calcium added.	Suspension.	Extract.	0.05N. HCl.	Calcium in extract.	Calcium not adsorbed.	Calcium adsorbed.
Mgm.	P_H	P_H	*Cc.*	*Mgm.*	*Mgm.*	*Mgm.*
0	5.56	7.83	0.0	1.2	0.0	0.0
4	6.78	7.96	.4	2.4	1.2	2.8
8	8.20	8.84	.6	3.0	1.8	6.2
12	9.42	9.48	.9	4.2	3.0	9.0
16	9.99	10.60	2.5	8.9	7.7	8.3
20	10.40	10.97	2.7	9.2	8.0	12.0
28	11.97	11.17	3.4	10.0	8.8	19.2
36	11.34	11.58	6.5	15.2	14.0	22.0
48	11.61	11.85	16.7	24.0	22.8	25.2
60	11.68	11.90	24.2	33.3	32.1	27.9
80	11.87	12.01	27.4	40.5	39.3	40.7

The hydrogen-ion concentration of the suspension of the ignited soil was very nearly the same as that obtained on the original soil in Experiment 5. This shows that the acid-producing substance was not destroyed by ignition. The hydrogen-ion concentration of the extract from the ignited soil was greater than it was in the original soil. This indicates that ignition increased the solubility of the acid-producing substance. However, the addition of the same quantities of $Ca(OH)_2$ to the ignited soil produced a greater increase in the hydroxyl-ion concentration. This was due to the decreased adsorption of calcium. The amount of calcium adsorbed by the ignited soil was approximately two-thirds that adsorbed by the original soil. The adsorptive capacity was lessened by the destruction of colloidal structure brought about by ignition. It is also possible that ignition alters the structure of the silicates in such a way that less chemical combination with calcium is possible. It is recognized that a too general statement can not be based on this experiment with only one soil. However, it is clear that while the hydrogen-ion concentration was not decreased by ignition, the adsorptive power for calcium was materially decreased.

EXPERIMENT 13.—IGNITED SOIL+CALCIUM HYDROXID+POTASSIUM CHLORID

The manner of procedure in this experiment was the same as in Expeirment 12 except that KCl was added. The results obtained are presented in Table XIII. The effect of KCl in increasing the hydrogen-ion concentration and decreasing the amount of calcium adsorbed was relatively the same on ignited soil as on the untreated soil. Ignition, however, decreased the solubility of calcium in a solution of KCl. In the original soil a solution of KCl dissolved 14 mgm. calcium per 10 gm. of soil, but in the ignited soil the amount dissolved was only 3.9 mgm. Thus while ignition increased the solubility of the acid-producing substances in a solution of KCl it decreased the solubility of calcium in the same solution. Preceding experiments have shown that calcium adsorption was decreased by the presence of KCl and also by ignition. This experiment shows that KCl added to the ignited soil results in a further decrease of calcium adsorption. This apparently means that while basic exchange took place less readily in the ignited soil, the substances formed were more highly ionized.

TABLE XIII.—*P_H suspensions and extracts of ignited soil+$Ca(OH)_2$+KCl, also titrations and calcium content of extracts and calcium adsorbed from $Ca(OH)_2$*

Calcium added.	Suspension.	Extract.	0.05N HCl	Calcium in Extract.	Calcium not adsorbed.	Calcium adsorbed.
Mgm.	P_H	P_H	*Cc.*	*Mgm.*	*Mgm.*	*Mgm.*
0	4.82	5.83	0.3	3.9	0.0	0.0
4	6.17	7.00	.0	6.9	3.0	1.0
8	7.76	7.59	.4	9.7	6.8	1.2
12	8.88	9.18	1.3	12.3	8.4	3.6
16	10.05	10.02	2.9	14.7	10.8	5.2
20	10.43	11.03	7.6	17.5	13.6	6.4
28	10.90	11.20	9.6	21.8	17.9	10.1
36	11.14	11.51	13.8	27.1	23.2	12.8
48	11.44	11.61	17.2	32.1	28.2	19.8
60	11.68	11.95	30.1	42.6	38.7	21.3

EXPERIMENT 14.—ACID-TREATED SOIL+CALCIUM HYDROXID. (SOIL LOW IN CALCIUM.)

One hundred gm. of soil, Oswego silt loam, were placed in a 2-liter glass-stoppered bottle and 2 liters 0.5N HCl added. The bottle was shaken for a while, and the contents were then allowed to digest for several days with occasional shakings. The soil was washed by decantation as long as it would settle clear, and finally washed on a Buchner funnel until the filtrate gave a neutral reaction to litmus. The soil was then dried and used in a manner similar to that of Experiment 5. The data obtained are given in Table XIV.

TABLE XIV.—*P_H of suspensions of acid-treated soil+$Ca(OH)_2$, also titrations and calcium content of extracts and calcium adsorbed from soil. (Soil low in calcium.)*

Calcium added.	Suspension.	0.05N HCl.	Calcium in extract.	Calcium not adsorbed.	Calcium adsorbed.
Mgm.	P_H	*Cc.*	*Mgm.*	*Mgm.*	*Mgm.*
8	3.70	−1.3	1.0	1.0	7.0
16	4.85	−.6	1.2	1.2	14.8
24	6.24	.0	2.8	2.8	21.2
36	7.35	.4	3.4	3.4	32.6
48	8.98	.6	4.5	4.5	43.5
60	9.42	2.3	8.1	8.1	51.9
80	9.72	3.4	10.8	10.8	69.2

The acid treatment greatly increased the hydrogen-ion concentration of the suspension. The small value of the titration figures in comparison with the figures for the amount of calcium in the extract indicates that most of the calcium was present in the form of a neutral compound. The ratio of the amount of calcium adsorbed in relation to the amount added was as great with an addition of 80 mgm. calcium in the form of $Ca(OH)_2$ as with 8 mgm., indicating that the adsorptive capacity was not reached. In view of this, the greater amount of calcium found in the extract was probably due to resolution of an adsorption compound of calcium.

EXPERIMENT 15.—ACID-TREATED SOIL+CALCIUM HYDROXID. (SOIL HIGH IN CALCIUM.)

The procedure in this experiment was the same as that in Experiment 14, except that the soil used was a Summit silt loam high in calcium. The data obtained are given in Table XV.

TABLE XV.—*P_H of suspensions from acid-treated soil, also titrations and calcium content of extracts and calcium adsorbed from $Ca(OH)_2$*

Calcium added.	Suspension.	0.05NHCl	Calcium in extract.	Calcium not adsorbed.	Calcium adsorbed.
Mgm.	P_H	*Cc.*	*Mgm.*	*Mgm.*	*Mgm.*
8	3.36	−1.6	0.7	0.7	7.3
16	3.43	−1.0	1.0	1.0	15.0
24	3.80	−1.2	1.2	1.2	22.8
36	4.31	−1.0	1.8	1.8	34.2
48	5.77	−.4	2.1	2.1	45.9
60	7.35	−.4	5.1	5.1	54.9
80	8.47	−.5	8.8	8.8	71.

The hydrogen-ion concentrations were greater than those in the previous experiment and were due, as shown by the titration figures, to the larger amount of free acid present. After the acid treatment this soil was more colloidal than the one the used in Experiment 14. The calcium adsorptive capacity was nearly the same in the two soils. The acid treatment may be considered a case of intense leaching. Under humid climatic conditions soils high in calcium will ultimately lose their calcium to such an extent that they are as much in need of calcium as some soils derived from acidic rocks.

EXPERIMENT 16.—ACID TREATED SAND+CALCIUM HYDROXID

Ordinary river sand was chosen for this experiment. It was first ground to an impalpable powder in a ball mill, then digested in HCl. Further treatment was similar to that of the two preceding experiments. The data obtained are given in Table XVI.

TABLE XVI.—*P_H of suspensions of acid-treated sand+$Ca(OH)_2$ also titrations and calcium on the extract, and calcium adsorbed from $Ca(OH)_2$*

Calcium added.	Suspension.	0.05NHCl	Calcium in extract.	Calcium not adsorbed.	Calcium adsorbed.
Mgm.	*P_H.*	*Cc.*	*Mgm.*	*Mgm.*	*Mgm.*
2	7.76	−0.3	0.8	0.8	1.6
4	8.03	−.1	1.4	1.4	2.6
6	8.40	.6	1.9	1.9	4.1
8	8.50	1.6	2.5	2.5	5.5
12	8.84	2.2	3.7	3.7	8.3
16	9.25	3.9	5.2	5.2	10.8
20	9.35	4.7	6.5	6.5	13.5

As compared with soil, sand requires a much smaller amount of $Ca(OH)_2$ to produce a corresponding change in the hydrogen-ion concentration. Beyond the addition of 6 mgm. calcium the titration figures together with the P_H values show that the greater part of the calcium in the extract was present as $Ca(OH)_2$. A small part may have been present as $CaCl_2$. While the amount of calcium adsorbed was much less than that obtained with soil, the ratio adsorbed to the amount added was large. Finely ground sand does adsorb calcium, and the ratio between the amount adsorbed and the amount added corresponds to the adsorption law.

GROUP C.—INFLUENCE OF CALCIUM HYDROXID AND POTASSIUM CHLORID ON P_H WHEN USED WITH FULLER'S EARTH, ALSO ON THE TITRATION AND THE CALCIUM CONTENT OF THE EXTRACTS

EXPERIMENT 17.—FULLER'S EARTH+CALCIUM HYDROXID

The fuller's earth used in this experiment was a white commercial product labeled "chemically pure." It was treated like the soil in Experiment 5. The data based on 10 grams of material are given in Table XVII.

TABLE XVII.—*P_H of suspensions and extracts of fuller's earth, also titrations and calcium content of extracts, and calcium adsorbed from $Ca(OH)_2$*

Calcium added.	Suspension.	Extract.	Titer 0.05N HCl.	Calcium in extract.	Calcium not adsorbed.	Calcium adsorbed.
Mgm.	P_H	P_H	*Cc.*	*Mgm.*	*Mgm.*	*Mgm.*
0	4.82	6.23	−0.1	4.4	0.0	0.0
4	7.08	7.62	.1	5.2	.8	3.2
8	7.76	7.76	.2	7.0	2.6	5.4
12	8.17	7.86	.2	8.0	3.6	8.4
16	8.37	8.00	.2	8.2	3.8	12.2
20	8.61	8.27	.4	8.8	4.4	15.6
28	8.91	8.57	.6	9.6	5.2	22.8
36	9.11	9.11	1.8	11.1	6.7	29.3
48	9.28	9.31	2.5	11.8	7.4	40.6
60	9.48	9.45	2.9	12.3	7.9	52.1

The P_H values obtained on the water suspension and the water extract of fuller's earth show that the hydrogen-ion concentration in both was greater than that obtained in an extract of soil, and, like the soil, that the hydrogen-ion concentration was greater in the suspension than in the extract. The acid-forming substance in fuller's earth was more soluble than it was in soil. This means a greater intensity of acidity in the former. The fuller's earth had a comparatively large amount of calcium in the water extract, which makes it difficult to calculate calcium adsorption except relatively. Since the ratio of the amount of calcium adsorbed to the amount added was as great with the largest as with the smallest quantity added, the adsorptive capacity was probably not reached. The adsorptive capacity of fuller's earth for calcium was greater than that of Oswego silt loam. The titration figures show that a comparatively small amount of calcium was present in the extract as hydroxid or carbonate. Some may have been present as a silicate in colloidal form, some as the soluble compound formed with the acid-forming substance in fuller's earth, and some as redissolved from the adsorption compound.

The reactions of fuller's earth with $Ca(OH)_2$ were found to be very similar to those of soil, except in degree. The acid-forming substance in fuller's earth is probably an aluminum silicate, and by inference it might be concluded that the acid-forming substance in soil is of a similar nature.

EXPERIMENT 18.—FULLER'S EARTH+CALCIUM HYDROXID+POTASSIUM CHLORID

This experiment was conducted in the same manner as Experiment 17, except that KCl was also added. The data obtained are given in Table XVIII.

TABLE XVIII.—*P_H on suspensions and extracts of fuller's earth+$Ca(OH)_2$+KCl, also titration and calcium content of extracts, and calcium adsorbed from $Ca(OH)_2$*

Calcium added.	Suspension.	Extract.	Titer 0.05N HCl.	Calcium in extract.	Calcium not adsorbed.	Calcium adsorbed.
Mgm.	P_H	P_H	*Cc.*	*Mgm.*	*Mgm.*	*Mgm.*
0	5.06	5.43	0.00	1.8	0.0	0.0
4	6.68	....	.00	6.0	4.2	.0
8	7.15	7.25	.15	9.9	8.1	.0
12	7.66	7.62	.15	13.5	11.7	.3
16	8.06	7.90	.25	17.1	15.3	.7
20	8.27	8.06	.35	20.5	18.7	2.3
28	8.64	8.34	.65	25.5	23.7	4.3
36	8.94	8.67	1.35	29.1	27.3	8.7
48	9.21	9.15	1.65	33.0	31.2	16.8
60	9.35	9.21	2.80	35.8	34.0	26.0

In the presence of KCl corresponding amounts of $Ca(OH)_2$ produced smaller decrease in the hydrogen-ion concentration, indicating that the)lubility and the ionization of the acid-forming substance in fuller's ırth are increased by KCl; in other words, there are more hydrogen ›ns to be neutralized by the hydroxyl ions from $Ca(OH)_2$. On the other and, in the presence of KCl calcium adsorption was entirely inhibited hen small amounts of $Ca(OH)_2$ were added, and greatly reduced with he larger amounts. The adsorption of considerable quantities of calium when the larger amounts of $Ca(OH)_2$ were added shows that the endency of the calcium ions to combine with the radical of the acidorming substance was not prevented by a large excess of K ions. One undred cc. of a 0.5N solution of KCl contain nearly 2,000 mgm. of otassium, and yet adsorption of calcium took place when from 20 to 60 ıgm. were added in the form of $Ca(OH)_2$. The net result of the presence f KCl was a greater hydrogen-ion concentration and larger amount of nadsorbed calcium. If the acid-forming substance produces a silicic acid he following ions are present:

$$\begin{array}{ll} KCl & \rightleftharpoons K^+{}_+Cl^- \\ Ca(OH)_2 & \rightleftharpoons Ca^+{}_+2\ OH^- \\ H_2SiO_3 & \rightleftharpoons 2\ H+SiO_3 \\ HOH & \rightleftharpoons H^+ + OH^- \end{array}$$

f this represents the ionic condition, the neutralization is due to the ıydroxyl ions from $Ca(OH)_2$ combining with the hydrogen ions of the cid-forming substance. From this standpoint the reaction can be conidered purely chemical. The potassium ions combine with the radicals f the acid-forming substance, producing a potassium compound. In he absence of KCl, as in Experiment 13, or when large amounts of calium are added, as in this experiment, calcium ions combine with the adicals of the acid-forming substance. Larger amounts of calcium combine in the absence of KCl, and the ratio between the amount which ombines and the amount added accords with the law of adsorption.

ROUP D.—COMPARISON OF VARIOUS SOILS IN RESPECT TO THE INFLUENCE OF CALCIUM CARBONATE, CALCIUM HYDROXID, AND POTASSIUM CHLORID UPON THE P_H, THE ADSORPTIVE POWER OF SOIL FOR CALCIUM FROM CALCIUM HYDROXID, AND THE CALCIUM SOLUBLE IN HYDROCHLORIC ACID AND POTASSIUM CHLORID SOLUTIONS

XPERIMENT 19.—COMPARATIVE POWER OF FOUR SOILS TO ADSORB CALCIUM FROM CALCIUM HYDROXID

The purpose of this experiment was to compare the calcium-adsorptive power of four soils. Neosho silt loam, Bates very fine sandy loam, Oswego silt loam, and Bates loam were used. Eight different solutions of $Ca(OH)_2$ were made and added to soil in different definite amounts. After the usual treatment, the unadsorbed calcium and also the P_H values were determined on the extracts. The data obtained based on 10 gm. of soil are given in Table XIX.

The Bates loam, a neutral soil, and Oswego silt loam, a moderately acid soil, both containing larger amounts of clay than the other two, adsorbed nearly the same amount of calcium. Neosho silt loam, less acid than Oswego silt loam, adsorbed the least. The outstanding physical property of this soil is its small amount of clay and large amount of silt.

The Bates very fine sandy loam adsorbed more than the Neosho silt loam, but less than the other two. This soil had the highest hydrogen-ion concentration of the four, but it contains a comparatively small

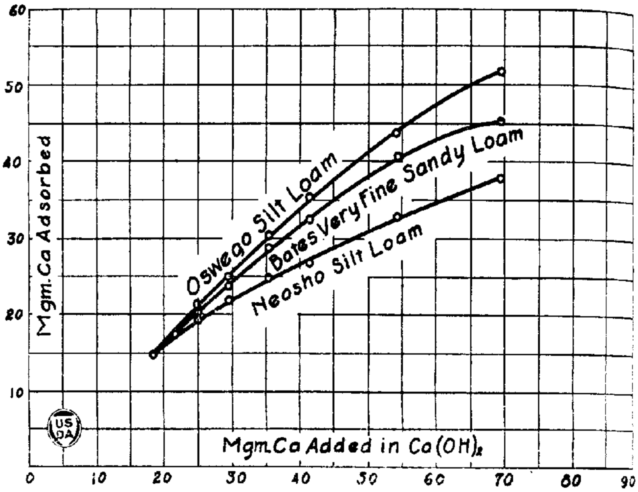

FIG. 7.—Comparative adsorption of calcium in soils (Experiment 19).

amount of clay. The main fact shown by this experiment is that the amount of clay is a factor of greater moment in calcium adsorption than is the initial intensity of acidity.

TABLE XIX.—*Adsorption of calcium from $Ca(OH)_2$ by four soils*

Calcium added.	NEOSHO SILT LOAM.			OSWEGO SILT LOAM.		
	Calcium in extract.	Calcium adsorbed.	Extract.	Calcium in extract.	Calcium adsorbed.	Extract.
Mgm.	*Mgm.*	*Mgm.*	P_H.	*Mgm.*	*Mgm.*	P_H.
18.7	3.4	15.3	9.43	3.4	15.3	8.59
21.8	4.3	17.5	10.04	3.9	17.9	8.52
25.2	5.6	19.6	10.55	3.6	21.6	8.52
29.1	7.1	22.0	10.79	4.0	25.1	9.16
35.4	10.4	25.0	11.26	4.8	30.6	9.60
41.5	14.2	27.3	11.50	6.1	35.4	10.58
54.5	21.2	33.3	11.73	10.5	44.0	10.82
69.1	31.0	38.1	11.90	17.2	51.9	11.43
	BATES VERY FINE SANDY LOAM.			BATES LOAM.		
18.7	3.8	14.9	8.52	3.8	14.9	8.26
21.8	4.0	17.8	8.55	3.9	17.9	8.52
25.2	4.3	20.9	8.66	4.3	20.9	8.52
29.1	4.7	24.4	9.67	4.6	24.5	9.30
35.4	6.4	29.0	10.41	5.3	30.1	9.91
41.5	9.0	32.5	10.95	6.6	34.9	10.24
54.5	13.8	40.7	11.36	9.1	45.4	10.85
69.1	23.9	45.2	11.73	14.5	54.6	10.95

EXPERIMENT 20.—COMPARATIVE POWER OF FOUR SOILS TO ADSORB CALCIUM FROM CALCIUM HYDROXID IN THE PRESENCE OF CALCIUM CARBONATE

The amounts of $CaCO_3$ equivalent to the calcium adsorbed in Experiment 19 were calculated and added to the dry soil. Fifty cubic centimeters of water was added to each bottle, the mixtures shaken for several hours, and then allowed to digest for one day. $Ca(OH)_2$ solutions were next added, and from this point on the experiment was performed like No. 19. The $Ca(OH)_2$ solutions were so adjusted that very nearly the same amounts of calcium were used per 10 gm. of soil as in the preceding experiment. The data obtained are presented in Table XX. The calcium adsorbed was calculated on the basis of the amounts added in the $Ca(OH)_2$ solutions.

TABLE XX.—*Adsorption by four soils in the presence of $CaCo_3$ of calcium from $Ca(OH)_2$*

$Ca(OH)_2$	NEOSHO SILT LOAM.			OSWEGO SILT LOAM.		
	Calcium in extract.	Calcium adsorbed from $Ca(OH)_2$	Extract.	Calcium in extract.	Calcium adsorbed from $Ca(OH)_2$	Extract.
Mgm.	*Mgm.*	*Mgm.*	P_H.	*Mgm.*	*Mgm.*	P_H.
17.9	3.6	14.3	9.53	4.6	13.3	8.62
21.3	4.2	17.1	10.11	4.2	17.1	8.75
25.4	6.0	19.4	10.72	4.2	21.2	9.18
27.9	7.0	20.9	10.95	4.7	23.2	9.64
34.2	10.9	23.3	11.40	5.2	29.0	10.55
40.9	14.5	26.4	11.53	6.8	34.1	10.97
50.3	20.3	30.0	11.66	10.4	39.9	10.36
68.2	31.9	36.3	11.90	17.2	51.0	11.70
	BATES VERY FINE SANDY LOAM.			BATES LOAM.		
17.9	4.0	13.9	8.45	5.4	12.5	8.72
21.3	4.7	16.6	9.37	5.6	15.7	8.77
25.4	4.8	20.6	9.72	5.4	20.0	9.18
27.9	5.7	22.2	10.06	5.4	22.5	9.21
34.2	7.6	26.6	10.97	5.6	28.6	10.70
40.9	10.0	30.9	11.22	6.5	34.4	9.60
50.3	15.1	35.2	11.53	9.4	40.9	11.17
68.2	26.0	42.2	11.80	17.3	50.9	11.63

The P_H values were not materially affected by the presence of $CaCO_3$. The excess of the hydroxyl ions was so large as to mask the influence of the HCO_3 and CO_3 ions. The addition of $CaCO_3$ under the conditions of this experiment did not change the relative adsorptive power of these four soils as found in Experiment 19. The presence of $CaCO_3$ only slightly reduced the amount of calcium adsorbed from $Ca(OH)_2$. In Experiment 7 it was found that $CaCO_3$ had practically no effect on calcium adsorption from $Ca(OH)_2$. The only difference in procedure between Experiments 7 and 20 was that in the latter case there was a longer contact for the $CaCO_3$ in the presence of water. While the effect of this longer contact was small it is enough to suggest that calcium is taken very slowly from $CaCO_3$ by the soil. The effect of long-time contact with $CaCO_3$ was also shown in Experiment 3.

EXPERIMENT 21.—THE H-ION CONCENTRATION OF SUSPENSIONS OF SOIL IN WATER AND IN A SOLUTION OF POTASSIUM CHLORID AND THE CALCIUM CONTENT OF HYDROCHLORIC ACID SOLUTIONS

In several preceding experiments it has been shown that the presence of KCl materially changes the P_H value of both soil suspensions and soil extracts. One of the difficulties encountered in making electrometric measurements on a soil suspension or extract is the possible diffusion of KCl from the contact tube. This is enhanced by the necessity of constant agitation of the electrode vessel and the long time required for making some of the measurements. It was desired to learn how serious a factor this is with different soils of varying calcium content.

Twenty-four soils with accompanying subsoils, taken in the soil survey from various parts of Kansas, were selected for this experiment. These soils had been analyzed for total calcium as well as other nutrients, and the resulting data as well as physical texture, as far as that is revealed by soil type, formed the basis of selection. The calcium soluble in cold 0.5N HCl was determined by digesting the soil at room temperature for 24 hours. The P_H values were determined both on the water suspensions and on the suspensions in the 0.5N KCl solution. Before taking the final voltmeter reading the rubber tube connecting the KCl solution reservoir and the capillary tube was opened slightly by pressing the pinchcock, so as to make fresh contact. This would introduce a small amount of KCl into the soil suspensions. Preliminary experiments had shown that the concentration of the KCl solution used as a solvent could be varied considerably without affecting the P_H values. The small quantity introduced by the manipulation just described would then have no effect on the suspension in which 0.5N KCl was used, but it might materially affect the water suspensions. It had been noticed several times in the preceding experiments that some of the soil colloidal matter would diffuse into the capillary KCl connecting tube. Just how much this influenced the reading was not known. When a KCl solution forms a part of the electrical connection with the calomel cell it is impossible to prevent some KCl entering the electrode vessel. If the system is so arranged that KCl forms part of the mixture in the electrode vessel the small quantity of KCl entering from this source may safely be ignored. The P_H values and the data on acid soluble calcium are given in Table XXI.

TABLE XXI.—*Hydrogen-ion concentration and calcium content of soil and subsoil*

Soil No.	County.	Soil type.	Surface.			Subsoil.		
			Calcium in HCl solution.	H_2O suspension.	KCl suspension.	Calcium in HCl solution.	H_2O suspension.	KCl suspension.
			Mgm.	P_H.	P_H.	*Mgm.*	P_H.	P_H.
31	Allen	Oswego fine sandy loam.	15.1	4.82	4.82	21.1	5.22	5.22
27	.....do	Oswego clay	34.8	5.02	4.82	50.4	5.77	5.53
23	.....do	Neosho silt loam	17.3	5.09	5.06	36.4	5.66	5.33
25	.....do	Osage loam	26.1	5.09	5.06	28.2	5.43	5.56
49	Montgomery	Crawford loam	18.4	5.12	4.82	25.0	5.80	5.60
11	Allen	Summit silt loam	35.1	5.16	5.06	189.6	7.46	7.93
17	Brown	Marshall silt loam	31.3	5.26	5.40	37.3	5.33	5.09
33	Allen	Summit silt loam	18.0	5.33	5.46	16.7	4.65	4.72
15	Riley	Oswego silt loam	33.0	5.39	5.33	74.0	7.16	7.72

'ABLE XXI.—*Hydrogen-ion concentration and calcium content of soil and subsoil*—Con.

			Surface.			Subsoil.		
›oil ło.	County.	Soil type.	Calcium in HCl solution.	H_2O suspension.	KCl suspension.	Calcium in HCl solution.	H_2O suspension.	KCl suspension.
			Mgm.	P_H.	P_H.	*Mgm.*	P_H.	P_H.
13	Allen..........	Oswego silt loam....	25.3	5.43	5.16	30.6	5.33	5.02
53	Brown.........	Marshall silt loam...	30.9	5.43	5.50	29.4	5.19	4.99
51	Leavenworth..	Brown loam.........	33.2	5.66	6.04	23.0	5.43	4.99
57	Barton.........	Greensburg sandy loam.	26.3	5.93	6.07	112.0	8.00	8.06
47	Cherokee.....	Oswego clay.........	39.8	5.97	6.17	154.2	7.08	6.98
21	Harper.......	Brown loam.........	14.2	6.07	6.10	16.8	6.78	6.51
39	Jewell.........	Lincoln clay........	42.2	6.27	6.44	54.8	6.71	6.68
41	....do........	Colby silt loam.....	27.2	6.41	6.34	78.0	7.66	7.66
19	Brown.........	Osage silt loam......	59.3	6.41	6.54	105.0	7.39	7.76
43	Greenwood....	Crawford silt loam...	31.8	6.48	6.64	78.0	6.85	6.85
35	Finney.......	Richland silt loam..	34.1	6.81	6.98	138.0	7.76	7.90
29	Allen..........	Oswego silt loam....	68.2	6.98	7.08	209.0	7.71	7.66
45	Greenwood....	Crawford clay.......	324.0	7.49	7.76	431.0	7.69	7.69
27	Jewell.........	Lincoln silt loam....	192.0	7.49	7.86	136.0	7.56	7.73
55	Gove.........	Colby silt loam......	78.4	7.49	7.96	284.0	7.90	8.23

The P_H values on the soil suspensions in water and in the KCl solu-ion do not differ widely except as will be noted. Hoagland and Sharp ?3) found that the diffusion of KCl into the electrode vessel had a ɜndency to increase the H-ion concentration, the amount of increase, owever, was small. It should be remembered that in soils P_H numbers ave no significance beyond the first decimal place. Considering the ifferent P_H values obtained, the general rule seems to be that the pres-nce of KCl increases the concentration of the H ion or the OH ion when ther is in marked excess. That is, in very acid soils the presence of Cl will increase the hydrogen-ion concentration, while in alkaline soil will increase the hydroxyl-ion concentration. If the P_H value obtained between 6 and 7 the influence of KCl is small.

As a rule, the calcium content is higher in the subsoil than in the ırface soil, and a higher calcium content is accompanied by a lower ydrogen-ion concentration. There were five soils which were exceptions) this, namely:

No. 13, Oswego silt loam.
No. 17, Marshall silt loam.
No. 33, Summit silt loam.
No. 51, Brown loam.
No. 53, Marshall silt loam.

ı these the differences in calcium content of soil and subsoil were nall. As a rule, the calcium content exerted a greater influence on the ɜaction than did the difference between soil and subsoil. When the ılcium content was high the P_H values ranged between 7.5 and 8.0, hich is also near the values obtained when adsorption of calcium from a$(OH)_2$ was complete.

EXPERIMENT 22.—P_H OBTAINED BY ADDING VARYING AMOUNTS OF CALCIUM HYDROXIDE TO DIFFERENT SOILS

By adding $Ca(OH)_2$ to a soil in such a way that several definite but varying amounts are used, and then determining the P_H values of the different portions, it should be possible to determine the equivalent $CaCO_3$ needed in the form of $Ca(OH)_2$ to give any desired P_H value. A number of the soils used in Experiment 21, the initial P_H number of which was less than 7, were selected for this experiment. Varying amounts of the $Ca(OH)_2$ solution and enough KCl to make the concentration 0.5N were added to three portions of soil. The amounts of $Ca(OH)_2$ to be added to the different soil portions were judged partly from the initial P_H value obtained on the soil suspension in KCl solution and partly by the general character of the soil. The solution was left in contact for the usual 24 hours. The results are given in Table XXII. The figures are grouped according to the decreasing value of the hydrogen-ion concentration.

TABLE XXII.—*Changes in P_H values produced by adding $Ca(OH)_2$ to different soils*

Soil No.	County.	Soil type.	Calcium added, mgm.			
			0	8	16	24
			P_H	P_H	P_H	P_H
31	Allen	Oswego fine sandy loam	4.82	6.14	7.35	8.03
27	....do	Osage clay	4.82	5.87	6.95	7.56
49	Montgomery	Crawford clay	4.82	6.31	7.39	7.96
11	Allen	Summit silt loam	5.06	6.34	7.32	......
23	....do	Neosho silt loam	5.06	6.61	7.52	8.67
25	....do	Osage loam	5.06	6.75	7.66	8.72
13	....do	Oswego silt loam	5.16	6.64	7.49	7.96
15	Riley	....do	5.33	6.64	......	7.76
17	Brown	Marshall silt loam	5.40	6.20	7.49	7.83
33	Allen	Summit silt loam	5.46	6.37	7.73	8.40
			Calcium added, mgm.			
			0	4.8	9.6	14.4
53	Brown	Marshall silt loam	5.50	6.20	6.95	7.13
51	Leavenworth	Brown loam	6.04	6.61	7.08	7.59
21	Harper	....do	6.10	7.25	7.86	8.56
			Calcium added, mgm.			
			0	2.4	4.8	7.20
57	Barton	Greensburg sandy loam	6.07	6.58	7.12	7.46
41	Jewell	Colby silt loam	6.34	6.75	7.20	7.49
39	....do	Lincoln clay	6.44	6.75	7.12	7.35
43	Greenwood	Crawford silt loam	6.44	6.95	7.08	7.37

There is in general a relationship between the initial hydrogen-ion concentration and the P_H values produced by the addition of a certain amount of $Ca(OH)_2$. If the initial hydrogen-ion concentration is high, a given amount of $Ca(OH)_2$ will produce a smaller change than if the

nitial concentration is low. This is due to the neutralizing effect of the cid-producing substance. Soil texture also has an influence on the esult, shown by the fact that a certain amount of $Ca(OH)_2$ will not roduce as great a change in the P_H values in clay and silt soils as in andy soils. Most soils in which the initial hydrogen-ion concentration orresponds to a P_H value of 5.5 or less required about 5 tons equivalent f $CaCO_3$ per acre to approximate the hydroxyl-ion concentration usually ound in soils of high calcium content.

XPERIMENT 23.—TOTAL CALCIUM OF SOILS AND CALCIUM SOLUBLE IN 0.5N HYDROCHLORIC ACID AND 0.5N POTASSIUM CHLORID SOLUTIONS

The soils used in Experiment 18 had been previously analyzed for total alcium in connection with the work of the State soil survey. The calium soluble in 0.5N HCl and in 0.5N KCl solution was determined by igesting at room temperature for 24 hours. The data obtained are resented in Table XXIII.

TABLE XXIII.—*Total calcium and calcium soluble in 0.5N HCl and in 0.5N KCl*

oil No.	County.	Soil type.	Surface soil.			Subsoil.		
			Total.	0.5N HCl	0.5N KCl	Total.	0.5N HCl	0.5N KCl
			Mgm.	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*
1	Allen	Oswego fine sandy loam.	25	15	15	27	21	23
7	....do	Osage clay	43	35	36	56	50	51
3	....do	Neosho silt loam	39	17	16	36	36	39
5	....do	Osage loam	50	26	25	41	28	28
9	Montgomery	Crawford loam	39	18	21	38	25	31
1	Allen	Summit silt loam	37	35	33	195	195	56
7	Brown	Marshall silt loam	45	31	26	57	37	38
3	Allen	Summit silt loam	37	18	16	31	17	19
5	Riley	Oswego silt loam	64	33	31	96	74	51
3	Allen	....do	36	26	26	41	31	35
3	Brown	Marshall silt loam	62	31	27	71	29	33
1	Leavenworth	Brown loam	58	33	27	59	24	27
7	Barton	Greensburg sandy loam.	58	26	18	134	112	33
7	Cherokee	Oswego clay	77	35	33	181	154	145
1	Harper	Brown loam	42	14	11	47	17	16
9	Jewell	Lincoln clay	104	42	39	172	54	44
1	....do	Colby silt loam	59	27	24	96	78	45
9	Brown	Osage silt loam	80	59	38	128	105	54
3	Greenwood	Crawford silt loam	49	32	29	60	57	40
5	Finney	Richland silt loam	81	34	26	421	139	33
9	Allen	Oswego silt loam	82	68	52	215	209	61
5	Greenwood	Crawford clay	320	321	47	311	434	33
7	Jewell	Lincoln silt loam	222	192	52	150	136	42
5	Gove	Colby silt loam	183	78	34	256	285	34

The total calcium obtained by the fusion method was uniformly eater than the calcium soluble in either the HCl or KCl solutions, d the differences were more marked in soils of low calcium content. is means that the lower the calcium content the lower the relative lubility. In soils of comparatively low calcium content the amount luble in a KCl solution was nearly the same as that soluble in a HCl

solution of the same normality. When soils contained a large amount of calcium the solubility in the KCl solution was much less than in HCl, and the difference increased with increasing amounts of calcium. In several of the preceding experiments it was shown that very little or no calcium was adsorbed in the presence of KCl when the amount added in $Ca(OH)_2$ was small. This indicates that the calcium is changed to a soluble salt. Considerable amounts of calcium were adsorbed in the presence of KCl when the added amount of $Ca(OH)_2$ was large. The power of KCl to change calcium in a soil to a soluble salt is limited. Calcium in soil is usually present as a silicate or a carbonate, a salt of a weak acid and strong base. When KCl is added to soil $CaCl_2$ and the potassium salts of the weak acids are formed, the reaction being often described as basic exchange (47). This is a reversible reaction, governed by the law of mass action.

GENERAL DISCUSSION

ORGANIC VERSUS INORGANIC ORIGIN OF ACIDITY

There are a number of theories relative to soil acidity, soil reaction, and lime requirements. Some of these are discussed by Fisher (*13*). The substance which determines whether the hydrogen ions or the hydroxyl ions shall be in excess may be of organic or inorganic origin. When organic matter decays in soil organic acids may be formed. Such a source of acidity is common in muck and peat soils (*29*, p. 355). In soils principally of mineral origin, organic matter apparently does not play an important rôle in the production of soil acidity (*11*, *25*). That a considerable amount of an organic acid may be added to such mineral soils without increasing the hydrogen-ion concentration was shown in the experiment with oxalic acid. In fact, the addition of small amounts of the feebly ionized acid actually increased the hydroxyl-ion concentration, probably because of the formation of salts of a weak acid and strong base. This explains the well-known fact that instead of increasing acidity the addition of organic matter may actually decrease the same.

All of the soils used in this study were derived mostly from limestone, lime shale, and sandstone. They were therefore typical mineral soils. That organic matter does not determine the reaction of such soils is shown again by the fact that after ignition (Experiment 12) the P_H values were not materially changed. The source of the excess hydrogen-ion concentration is in the mineral portion of the soil. Harris (*17*, *18*, *19*) found many acid soils that were deficient in organic matter. Most acid soils are of mineral origin, and organic matter is only an indirect factor in the production of the acid condition.

ACID CONDITION PRODUCED BY WEATHERING

The cause of the acid condition of a mineral soil is due to chemical changes which are a part of the weathering process, or the process by which soils are formed from rocks and minerals. Acid soils are likely to be found where the annual rainfall exceeds evaporation, and alkaline soils when the opposite condition prevails. Continuous addition of $NaNO_3$, $(NH_4)_2SO_4$, or $CaH_4(PO_4)_2$ may also affect soil reaction (*5*, *10*).

When silicates, such as the feldspars, undergo weathering the chemical changes which take place may be represented by the equation:

$$K_2O \cdot Al_2O_3 \cdot 6\ SiO_2 + CO_2 + 2H_2O = K_2CO_3 + 4SiO_2 + Al_2O_3 \cdot 2\ SiO_2 \cdot H_2O$$

The reaction is similar when calcium or some other strong base is present in the original mineral. The base sodium has been removed from soils in humid regions to such an extent that very little is left. Under present climatic conditions calcium is the base removed in largest amount (*22*, p. 22–23). Since the earth's crust contains nearly the same percentage of potassium and sodium (*9*), and also since soils of mineral origin contain more potassium than sodium, it is indicated that potassium is less readily removed.

In the Tropics, where the conditions of weathering are more intense, the process goes further than that represented by the above equation. The equation for this more intense transformation may be written (*34*)—

$$K_2O \cdot Al_2O_3 \cdot 6\ SiO_2 + 3\ H_2O + CO_2 = 2\ Al\ (OH)_3 + K_2CO_3 + 6\ SiO_2.$$

The similarities and differences of the two equations are apparent. Both show that the bases are transformed into soluble forms, and in this condition may be readily removed by leaching. However, in the formation of the alumino-silicate, kaolin, only two-thirds of the silica is set free from the original mineral. In tropical weathering, according to the above equation, all the silica is split off and the aluminum is found as the hydroxid, gibbsite, the characteristic mineral of laterite.

REMOVAL OF BASES THE FUNDAMENTAL CAUSE OF ACIDITY

The elements potassium, sodium, and calcium in those minerals which form soil are in a condition of unstable chemical equilibrium under humid climatic conditions. They form the weak link in the mineral molecule. Under the conditions of a humid climate they are removed by various agencies, and the more stable alumino-silicates found in clay are produced. This removal of bases is the fundamental cause of the acid condition of soil of mineral origin.

Cameron and Bell (*6*) give another picture of the chemical transformations which take place in the weathering of silicates. They write the equation as follows:

$$KAlSi_3O_8 + HOH = KOH + HAlSi_3O_8$$

The successive removal of silica is represented as follows:

$$HAlSi_3O_8 - SiO_2 = HAlSi_2O_6, \text{ pyrophyllite.}$$
$$HAlSi_2O_6 - SiO_2 = HAlSiO_4, \text{ kaolinite.}$$
$$HAlSiO_4 - SiO_2 = HAlO_2, \text{ diaspore.}$$

This chemical reaction explains the alkaline reaction of finely ground suspension of orthoclase in water. Under humid condition the base is removed and the acid alumino-silicate is left. This is very slightly soluble and feebly ionized.

The equations also show the splitting off of silica, and, at present, considerable amounts are being leached from the land surface (*22*, p. 22–23). This may be removed, at least in part, in the colloidal form (*24*). But the serious loss is that of calcium, which under climatic conditions is leached in large amounts from cultivated land. (*30*)

The carbon dioxid needed for this weathering process is derived partly from that brought to the soil in rain (*9*), and perhaps to a larger extent from the decay of organic matter in the soil. In this way organic matter indirectly brings about an acid condition of the soil.

IMPOVERISHMENT OF CALCIUM, THE END RESULT OF WEATHERING

The net result of the weathering process is the removal of bases, mostly in carbonate form, the production of free silica, and the accumulation of the alumino-silicates. The presence of calcium in soil in the noncarbonate form indicates that all of the calcium has not been removed from these silicates. A large part of this calcium is soluble in dilute hydrochloric acid and in a 0.5N solution of KCl. In this process the potassium is taken up by the silicate and the calcium is set free in equivalent amounts (*36*). This process is usually called basic exchange (*43, 46, 47*). The ionic and adsorption theories show that calcium is made soluble because of the excess of hydrogen and chlorin ions when the adsorption of potassium takes place. The weathering process produces a soil poor in calcium. Plants need calcium for growth and development. What is often called an acid condition exists when calcium is so firmly combined with the alumino-silicates that it is unavailable for plant use. Under such a condition calcium supplied even in the form of $CaSiO_3$ may be beneficial, not because it reduces the hydrogen ions, but because it satisfies the need of plants for calcium. When calcium in the form of $Ca(OH)_2$ is added to soils which contain these alumino-silicates the basic condition of the original mineral tends to be restored. Such recombination may be purely chemical. If this is true, there are an indefinite number of alumino-silicates in which calcium is only partly taken up. This was shown in several experiments in which the amount of calcium adsorbed was definitely related to the amount added.

ACID NATURE OF WEATHERED ALUMINO-SILICATES

The acid nature of weathered silicates, or the property which makes them combine with bases, can be seen from the following explanation based on Clarke's theory (*8*). The simplest method of representing many, perhaps all, of the orthosilicates of aluminum is as substitution derivatives of the normal salt $Al_4(SiO_4)_3$ derived from the normal silicic acid H_4SiO_4. The existence of this silicate has not been proved, but several minerals such as nephelite, $NaAlSiO_4$, leucite, $KAlSiO_4$ and Kryptolite, $HAlSiO_4$, in which one or more atoms of aluminum are replaced by other metals, are known. The acid nature of the latter is suggested both by the formula and by the substitution of hydrogen for the bases potassium and sodium.

The structural formulas (*8*) of the normal aluminum silicate and kaolinite suggests the acid nature of the latter.

Normal silicate.	Kaolinite.
$Al \begin{cases} SiO_4{=}Al \\ SiO_4{=}Al \\ SiO_4{=}Al \end{cases}$	$Al \begin{cases} OH \\ SiO_4{=}H_2 \\ SiO_4{=}Al \end{cases}$

It is well known that kaolin has an acid reaction toward indicators. Fuller's earth, a substance of the same chemical nature as kaolin, gave

(Experiment 13) a P_H value indicating a higher hydrogen-ion concentration than that found in many acid soils. The adsorptive power for calcium was also greater. The silicates present in such materials as fuller's earth and kaolin are relatively insoluble and very feebly ionized. Rice and Osugi (*39*) found that the catalytic effect of the hydrogen ion from some silicates as indicated by the inversion of cane sugar was nil when KCl was absent, but considerable when this salt was present. The greater hydrogen-ion concentration produced by adding a neutral salt like KCl to an alumino-silicate is due to the adsorption of potassium (*36*), thus increasing the number of hydrogen ions. When a soil is suspended in water and agitated, some bases readily go into solution, as is well known by the analysis of the water extracts. Some of the hydrogen ions in a water suspension can be accounted for by the readsorption and consequent rearrangement of bases.

ADSORPTION VERSUS CHEMICAL COMBINATION

Whether the changes which occur when a hydroxid such as $Ca(OH)_2$ is added to soil shall be considered purely a chemical reaction or more in the nature of an adsorption phenomenon has been the subject of considerable study (*3, 17, 18, 19, 45*). Recent ideas (*16, 27*) concerning the relationship between molecules, such as occur in the formation of crystals, and the phenomena of adsorption would point to the conclusion that there is no sharp dividing line between a purely chemical union of elements or compounds and adsorption. If it is true that chemical compounds form when $Ca(OH)_2$ is added to soil, then from the experimental data here presented there must be an indefinite number of such compounds, all with different formulas. It is simpler to assume ordinary adsorption as an explanation.

THE PROCESS OF ADSORPTION

The process of adsorption was demonstrated in the experiment of Linder and Picton (*28*), who showed that when As_2S_3 is precipitated from colloidal solution by $BaCl_2$ a certain amount of the barium is carried down and a corresponding amount of HCl produced. Parker (*36*) found that when an acid soil is shaken with a solution of KCl the potassium is displaced by aluminum and other bases in nearly equivalent amounts, the chlorin remaining unchanged. However, when NaOH was also added together with the KCl his data showed that just as much potassium was absorbed, but no calcium liberated. The following equations illustrate what takes place:

$$KCl \rightleftharpoons K^+ - Cl$$
$$HOH \rightleftharpoons OH + H^+$$
$$KOH\ (\text{adsorbed}) + HCl$$

In soils of relatively low calcium content the solubility of this element (Experiment 23) in 0.5N KCl was the same as in 0.5N HCl. The above equations show that in reality HCl is the dissolving agent. If a base like NaOH is present, NaCl is formed and no calcium is dissolved.

THE CAUSE OF THE LOW INTENSITY OF SOIL ACIDITY

If the HCl formed when potassium is adsorbed from KCl remained uncombined, then the increase in hydrogen-ion concentration would be much larger than it is normally. Calcium silicates are present, and the further reaction may be represented as follows:

$$HCl + \text{Ca silicate} \rightleftharpoons CaCl_2 + \text{H silicate}.$$

The relatively small hydrogen-ion concentration is due to the hypothetical feebly ionized silicic acid or the acid salt. The larger the amount of calcium in the soil, even in the form of silicates, the less the hydrogen-ion concentration. This is also the reason why in the presence of a small intensity of acidity, a relatively large amount of base such as $Ca(OH)_2$ is necessary to shift the equilibrium from a high to a lower hydrogen-ion concentration. This fact was shown in several of the preceding experiments.

HARMFUL EFFECTS OF ALUMINO-SILICATES

Several investigators (*1*, *10*, *20*) have shown the harmful effect upon plant growth of aluminum in some soils. The net result of the weathering process is the enrichment of aluminum in the mineral matter of the soil at the same time that there is an impoverishment of the bases. In tropical weathering this is carried to the extreme, as has already been shown. The luxuriant vegetation of the Tropics would indicate that the accumulation of aluminum is not in itself harmful. Just why aluminum compounds should be toxic under some conditions and not toxic under such extreme conditions as laterite weathering is a problem which apparently has not been investigated. The explanation probably lies in the nature of the subsoil. If the subsoil is open, transference of matter takes place more readily and a better balance is maintained. The addition of calcium compounds removes the toxic effect of aluminum (*20*). The cycle of aluminum in nature and its effect on the physiological activities of plants is given by Stocklasa (*42*).

ADSORPTION OF CALCIUM AS A PROCESS OF REPLACEMENT

The presence of such alumino-silicates as are produced by weathering probably accounts for the adsorption of calcium from such compounds as $Ca(OH)_2$ and $CaCO_3$. Leaching and treatment with acids, both of which may be considered as intensified processes of weathering, increased the adsorptive power of the soil (see Experiments 11 and 14). Calcium adsorption was the same whether the original acid-treated soil was high or low in calcium (see Experiments 14 and 15). The adsorptive power is conditioned upon the alumino-silicates that are produced by those processes which make soil. Adsorption in soils is a process of replacing the lost base.

RELATIVE ADSORPTION OF CALCIUM AND POTASSIUM

When KCl is present in large amounts the need of these alumino-silicates for a base is satisfied. When the ratio of calcium to potassium was very small no calcium adsorption took place. When the ratio of

calcium to potassium was 1 to 30 about half as much calcium was adsorbed as in the absence of KCl, and considerable was adsorbed even with a wider ratio. This indicates that the adsorptive power of these alumino-silicates for calcium is greater than for potassium.

CONCLUDING STATEMENT

The process of weathering removes by degrees the bases in soils, and hence alumino-silicates are present with varying amounts of bases. The definite composition of many supposed minerals is questioned (*38*). If definite calcium aluminates exist, an equilibrium must have been reached (*38*). In the absence of such an equilibrium a heterogeneous mixture is present. If the removal is gradual, and substances are present with varying amounts of bases, the recombination would also be gradual. These may be purely chemical combinations, but, if so, the quantitative relationship is as would be expected by the adsorption law. This has been shown in Experiments 5 to 18. The amount of calcium adsorbed bears a certain relation to the amount added. The total amount adsorbed increases according to the amount added. When relatively small amounts are added, all is adsorbed. When larger amounts are added the greater part is adsorbed. Adsorption is further emphasized by the fact that the amount of clay has a greater effect on the amount of calcium adsorbed than the intitial hydrogen-ion concentration (Experiments 19 and 22).

Many problems have been suggested by the present investigation. There are a number of factors which affect the electrometric measurements on soils. The hydrogen electrode does not give as satisfactory results with soils as it does with many other materials. The phenomenon of poisoning the electrode that exists with other materials is worse with soil. There is great need of standardizing the electrometric method for soils. Several of the experiments should be repeated on a more extensive scale; particularly those on the effect of organic acids on soils; leaching; ignition; and the acid treatment. More knowledge is needed concerning the solubility of the acid-forming substance in soil. The adsorption of the hydroxyl ions, only incidentally touched upon, needs further investigation.

SUMMARY

1. Acidity or alkalinity of aqueous solutions is expressed by the symbol P_H and some number which denotes the degree of the hydrogen-ion or the hydroxyl-ion concentration. The ion in excess determines whether the solution is acid or alkaline. This general concept is applied to water solutions and water suspensions of soil. The hydrogen-ion concentration in soil was measured with the hydrogen electrode. When used with soil this method presents many difficulties; these, however, are not necessarily insurmountable.

2. Since surface plays an important part, and phenomena of heterogeneity are manifest, the term adsorption rather than absorption is used to describe the combination of soil and $Ca(OH)_2$. Quantitatively, the combination obeys the adsorption law.

3. Successful use of the hydrogen electrode with soils depends on effective methods and efficient apparatus. A special apparatus was devised by which it is possible to carry on six electrode measurements at the same time with the minimum attention of the operator.

4. A large part of the experimental work was done on one soil, with supplementary work on other soils and materials. Calcium in the form of $Ca(OH)_2$ was added to soil in various amounts and the P_H values and unadsorbed calcium determined. This was done both in the presence and absence of KCl. $CaCO_3$ was also used in some experiments.

5. The general effect of KCl was to increase the hydrogen-ion concentration except in soils which have a comparatively large amount of calcium. It reduced calcium adsorption from zero to one-half, more being adsorbed with the larger amount of $Ca(OH)_2$ added.

6. The hydrogen-ion concentration was greater on the suspensions than on the extracts except where there was an excess of hydroxyl ions. Leaching a soil did not decrease the hydrogen-ion concentration nor the adsorptive power; the last of these, however, was decreased by ignition. The addition of $CaCO_3$ and $Ca(OH)_2$ did not materially affect the P_H values unless there was a long period of contact with the $CaCO_3$. The amount of calcium adsorbed from $Ca(OH)_2$ was not affected by the presence of $CaCO_3$. The adsorptive power of soil was more closely related to the clay content than to the original hydrogen-ion concentration.

7. Fuller's earth had a higher hydrogen-ion concentration and a greater adsorptive power than soil.

8. The hydrogen-ion concentration and adsorptive power of soil when treated with hydrochloric acid and washed was the same irrespective of the original calcium content of the soil.

9. Addition of small amounts of 0.04N HCl increased the hydrogen-ion concentration proportionally to the amount added. Oxalic acid of the same concentration decreased the hydrogen-ion concentration with the smaller portions of acid, and increased it with the larger portion of acid. This increase was not as great as with equivalent amounts of HCl. The difference in the effect of the two acids is due to the formation of feebly ionized salts of a weak acid and strong base in the case of the oxalic acid.

10. The fundamental cause of the acid condition of a mineral soil is found in the chemical changes which accompany weathering. The bases are removed and acid alumino-silicates accumulate. Since the removal of bases takes place gradually, readsorption would take place in a like manner. The harmful effect of these alumino-silicates is not necessarily due to the higher hydrogen-ion concentration, but more probably to the adsorption of calcium to such an extent that not enough is available for plant use. The amount of calcium adsorbed when definite amounts of a solution of $Ca(OH)_2$ is added to soil and the P_H value produced can be measured by the methods described.

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TIME FOR TESTING MOTHER BEETS[1]

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In the investigations carried on during the past three years at Salt ,ake City Station, great irregularity has been noted in the quantity of ıgar lost by individual sugar beets during storage. Sugar beets stored nder ordinary silo conditions for three months lose from a few tenths f 1 per cent to 8 per cent of sugar. This means that of two beets each ɔntaining 16 per cent sugar at harvest one might, after storage test 15.8 nd the other 10 per cent sugar. One may also find beets (a) of 20 and ɔ) of 17 per cent sugar at harvest time, showing spring tests (after :orage) of 12 and 16 per cent sugar, respectively. This irregularity in ıe percentage and quantity of sugar lost by individual beets during silo .orage is also to be found in beets stored under controlled moisture and :mperature conditions. Yet the State experiment stations and the ıgar beet companies which are developing their own seed, following ıe common practice, are at the present time still testing their sugar eets in the spring after these beets have been stored over winter. In iew of these facts the question of the proper time for mother-beet testıg forces itself upon us for immediate consideration.

HISTORICAL

Friedl[2] in 1912 tested 340 beets before and after storage. These beets ›st from 1 to 10 per cent of sugar during storage. He also worked in ›nnection with several sugar factories on the loss of sugar by commeral beets during storage. From his studies he concluded that there was heavy loss of sugar in beets during storage.

METHODS

This paper deals only with beets which were stored as usual in an ›rdinary silo. The beets were harvested during October, 1922, tested, veighed, and placed in storage during November, 1922. After 98 days in torage the same beets were weighed and tested as before. A special nachine made at this station which permits the same beet to be sampled everal times without injury was used. All beets tested by this machine ame through the storage period in perfect condition. No rot or decay vas found, and every beet that had been tested in the fall was again tested n the spring. The exceptionally good condition of these beets was due o the improved methods of sampling and storing employed.

A number of beets were sampled two or three times each, and the ampling method was found satisfactory from a chemical standpoint. The samples taken from beets after storage were sufficiently separated rom the cuts made before storage to insure against oxidation and other

[1] Accepted for publication Aug. 24, 1923.

[2] FRIEDL, Gustave. EIN BEITRAG ZUR FRAGE DER VERÄNDERUNG DER ZUCKERRÜBE WÄHREND DER UFBEWAHRUNG. *In* Österr. Ungar. Ztschr. Zuckerindus. u. Landw., Jahrg. 41, p. 698–712. 1912.

tissue changes occurring during storage. The chemical analysis wa made according to the method devised and described by S. F. Sherwoo chemist, Sugar-Plant Investigations, United States Department (Agriculture.[3]

RESULTS

Table I gives the tag numbers of beets, the percentage of sugar a harvest (fall test), percentage of sugar after storage (spring test), an the difference in the percentage of sugar before and after storage.

TABLE I.—*Percentage of sugar shown by fall and spring tests and the difference betwe the two*

Tag. No.	Fall test.	Spring test.	Difference.	Tag No.	Fall test.	Spring test.	Difference.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per ce*
1	19.0	13.2	5.8	96	16.4	16.0	.
2	17.4	12.6	4.8	97	17.4	16.2	1.
4	16.0	12.6	3.4	98	18.4	15.2	3.
8	17.6	12.8	4.8	99	18.4	15.0	3.
9	16.4	14.2	2.2	100	19.0	16.0	3.
18	17.4	14.2	3.2	101	20.0	16.4	3.
19	14.6	12.4	2.2	102	19.4	15.4	4.
20	18.6	15.0	3.6	103	18.4	17.8	.
22	18.2	14.6	3.6	104	18.4	16.4	2.
23	17.6	14.2	3.4	106	17.2	15.4	1.
24	17.8	14.0	3.8	109	19.0	16.2	2.
25	18.0	14.6	3.4	110	20.4	18.0	2.
27	16.8	12.4	4.4	111	17.6	14.4	3.
28	17.0	12.8	4.2	113	17.6	14.4	3.
29	16.8	14.0	2.8	114	17.6	15.2	2.
30	16.8	14.0	2.8	115	15.6	12.6	3.
31	18.0	13.6	4.4	116	18.2	15.6	2.
35	16.2	14.6	1.6	117	18.2	14.6	3.
36	17.4	14.0	3.4	119	20.6	16.2	4.
39	20.0	16.6	3.4	120	18.2	13.6	4
41	17.8	14.4	3.4	121	18.8	14.8	4.
44	19.2	16.2	3.0	122	18.6	14.4	4
46	17.6	14.6	3.0	123	17.0	14.2	2.
47	17.6	13.6	4.0	124	18.6	14.4	4
48	17.2	13.2	4.0	125	18.8	15.8	3.
49	18.0	14.2	3.8	126	19.6	15.6	4
54	16.8	14.0	2.8	127	17.6	15.0	2.
55	16.2	14.6	1.6	128	15.6	14.4	1.
56	17.6	14.4	3.2	129	19.0	16.0	3.
58	17.4	13.0	4.4	130	18.4	16.6	1.
70	17.6	15.2	2.4	131	17.8	14.0	3.
74	19.6	17.0	2.6	132	18.4	15.6	2.
78	17.4	14.0	3.4	133	19.2	15.0	4
79	21.0	15.8	5.2	134	20.0	14.2	5.
81	19.4	14.8	4.6	137	16.2	12.8	3.
84	15.4	13.8	1.6	138	17.4	13.0	4
86	18.2	14.4	3.8	139	18.8	16.2	2.
87	15.6	13.2	2.4	140	20.6	16.4	4
88	17.4	15.6	1.8	141	15.4	12.8	2.
89	17.8	14.4	3.4	142	17.2	15.0	2.
90	17.2	14.6	2.6	143	18.4	16.8	1.
91	16.6	13.6	3.0	144	14.4	10.6	3.
92	16.0	14.0	2.0	145	19.2	16.0	3.
93	18.4	14.0	4.4	146	17.0	13.6	3.
94	19.2	16.4	2.8	147	17.8	15.0	2.
95	16.6	12.8	3.8	148	19.2	16.4	2.

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[T]ABLE I.—*Percentage of sugar shown by fall and spring tests and the difference between the two*—Continued

Tag. No.	Fall test.	Spring test.	Difference.	Tag No.	Fall test.	Spring test.	Difference.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
49	18.8	16.2	2.6	227	19.6	15.6	4.0
50	18.4	15.0	3.4	228	17.4	14.8	2.6
51	18.0	15.6	2.4	229	20.4	15.6	4.8
52	20.0	15.4	4.6	230	18.4	15.2	3.2
53	18.4	15.2	3.2	231	19.4	15.6	3.8
54	20.6	16.0	4.6	232	20.2	16.0	4.2
55	20.4	17.2	3.2	233	20.8	17.6	3.2
56	20.2	15.6	4.6	234	20.4	17.8	2.6
57	20.4	15.0	5.4	235	20.6	16.6	4.0
58	19.0	15.6	3.4	236	19.4	15.6	3.8
59	19.4	15.6	3.8	237	18.0	15.0	3.0
60	19.4	15.0	4.4	238	19.8	16.8	3.0
65	17.8	15.0	2.8	239	16.8	14.8	2.0
68	18.0	16.6	1.4	240	18.8	15.4	3.4
73	18.0	14.6	3.4	241	21.4	18.0	3.4
74	17.4	14.6	2.8	242	18.6	16.2	2.4
75	17.2	14.0	3.2	243	20.0	17.4	2.6
76	18.2	16.0	2.2	244	19.2	16.6	2.6
77	18.4	17.4	1.0	245	18.2	15.4	2.8
78	19.6	16.8	2.8	246	20.8	17.0	3.8
80	17.4	15.0	2.4	247	20.8	16.6	4.2
83	20.0	16.4	4.0	248	19.0	15.2	3.8
86	20.4	17.2	3.2	249	20.0	17.4	2.6
90	17.6	17.0	.6	250	18.8	16.0	3.8
91	21.2	18.8	2.4	252	19.4	16.0	3.4
92	19.8	16.2	3.6	253	19.6	15.6	4.0
93	19.0	16.0	3.0	254	19.2	15.0	4.2
94	20.4	15.6	4.8	255	18.6	16.0	2.6
95	20.0	17.8	2.2	256	19.2	16.0	3.2
96	20.0	12.2	7.8	257	18.6	14.4	4.2
97	21.0	16.8	4.2	258	18.4	15.4	3.0
98	19.2	16.0	3.2	259	19.4	16.4	3.0
99	20.0	18.0	2.0	260	17.6	17.0	.6
00	20.6	15.4	5.2	261	18.4	14.8	3.6
01	18.4	16.0	2.4	262	19.8	16.4	3.4
02	21.0	17.4	3.6	263	19.4	15.6	3.8
03	17.6	14.2	3.4	264	18.6	14.4	4.2
05	19.6	17.4	2.2	265	18.8	16.6	2.2
06	19.0	15.2	3.8	266	19.0	16.6	2.4
07	17.0	14.6	2.4	267	19.6	16.8	2.8
08	18.0	13.6	4.4	268	18.6	16.0	2.6
09	20.8	15.8	5.0	269	18.6	15.6	3.0
0	19.2	15.6	3.6	270	18.4	15.6	2.8
1	20.6	17.6	3.0	271	19.2	14.6	4.6
2	16.6	14.6	2.0	272	19.6	16.4	3.2
3	20.0	16.0	4.0	273	18.4	14.4	4.0
4	17.8	14.0	3.8	274	17.4	15.0	2.4
5	18.8	15.8	3.0	275	18.8	15.8	3.0
6	17.2	14.2	3.0	276	16.8	12.8	4.0
7	17.6	13.6	4.0	278	19.4	15.6	3.8
8	21.0	16.0	5.0	279	18.2	15.4	2.8
9	19.2	15.4	3.8	280	18.8	16.0	2.8
0	18.0	14.8	3.2	281	17.6	14.0	3.6
1	17.4	13.2	4.2	283	16.6	13.4	3.2
2	18.4	11.6	6.8	286	18.8	14.8	4.0
3	18.4	14.8	3.6	287	15.8	14.0	1.8
4	18.0	13.4	4.6	288	20.0	15.6	4.4
5	15.4	13.8	1.6	289	18.8	16.4	2.4
6	18.8	12.0	6.8	290	17.4	14.4	3.0

TABLE I.—*Percentage of sugar shown by fall and spring tests and the difference betw the two*—Continued

Tag. No.	Fall test.	Spring test.	Difference.	Tag No.	Fall test.	Spring test.	Difference.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
291	19.4	15.2	4.2	391	21.6	15.6	6.
292	18.0	13.6	4.4	393	18.8	15.4	3.
293	19.4	16.6	2.8	394	18.6	15.0	3.
294	18.4	14.8	3.6	395	17.0	12.8	4.
295	20.2	17.0	3.2	396	19.8	17.0	2.
296	21.8	18.8	3.0	398	20.0	17.2	2.
297	19.0	15.4	3.6	400	20.0	15.6	4.
298	18.8	16.2	2.6	401	18.6	15.0	3.
299	18.6	15.8	2.8	402	20.0	17.0	3.
300	20.4	16.8	3.6	403	17.4	14.0	3.
305	16.6	14.4	2.2	404	17.0	13.6	3.
306	18.6	16.0	2.6	405	18.8	14.8	4.
307	18.6	16.6	2.0	406	17.2	13.4	3.
308	17.4	14.0	3.4	407	16.4	13.4	3.
309	18.0	16.6	1.4	410	19.4	15.6	3.
310	18.4	15.6	2.8	412	17.0	13.8	3.
311	18.2	15.2	3.0	413	16.8	12.4	4.
312	18.4	15.4	3.0	415	18.2	15.6	2.
313	17.4	15.6	1.8	416	19.6	16.2	3.
314	18.0	14.4	3.6	417	17.8	15.8	2.
317	20.2	16.6	3.6	419	14.4	12.4	2.
321	19.8	15.6	4.2	420	18.4	14.8	3.
323	18.6	15.0	3.2	423	18.8	14.2	4.
325	17.4	14.0	3.4	425	20.0	14.2	5.
326	17.4	14.8	2.6	429	18.0	14.6	3.
327	18.8	14.0	4.8	430	20.0	16.2	3.
329	20.2	17.0	3.2	432	19.6	15.8	3.
332	19.0	16.0	3.0	435	20.6	17.0	3.
333	21.6	16.8	4.8	436	21.6	19.0	2.
335	21.2	17.8	3.4	439	20.2	17.6	2.
337	18.8	13.6	5.2	440	21.2	16.4	4.
340	18.8	14.6	4.2	444	17.6	13.8	3.
341	17.2	14.0	3.2	445	22.4	16.8	4.
343	17.0	14.8	2.2	446	19.0	15.4	3.
346	19.4	15.0	4.4	449	20.4	17.6	2.
349	21.4	18.0	3.4	450	20.6	16.0	4.
352	17.6	13.8	3.8	451	21.4	18.0	3.
354	19.8	12.4	7.4	452	19.6	17.0	2.
356	18.0	14.8	3.2	455	21.0	15.6	5.
357	20.6	16.4	4.2	457	17.6	14.8	2.
358	15.2	12.4	2.8	459	20.8	16.4	4
365	15.6	13.6	2.0	462	20.6	16.8	3
366	19.2	15.6	3.6	464	20.8	17.0	3
368	19.8	15.8	4.0	469	20.8	15.6	5
369	19.8	15.2	4.6	470	20.8	15.6	5
370	18.0	15.8	2.2	471	18.8	16.2	2.
371	17.8	14.4	3.4	472	22.0	16.8	5.
373	21.0	17.4	3.6	473	20.0	13.4	6.
375	18.4	15.8	2.6	474	21.0	18.0	3.
376	18.4	15.0	3.4	475	21.2	16.4	4
379	19.2	15.2	4.0	477	21.4	17.2	4
380	18.2	14.8	3.4	478	20.6	14.4	6.
381	18.8	14.8	4.0	479	21.4	17.0	4
382	18.0	16.0	2.0	480	19.4	16.8	2.
383	18.8	16.2	2.6	482	22.2	16.2	6.
385	18.0	14.0	4.0	484	21.6	18.8	2.
386	20.2	15.2	5.0	488	20.4	16.0	4
387	20.6	17.0	3.6	492	17.6	12.4	5
388	19.8	16.6	3.2	494	18.4	15.6	2.

BLE I.—*Percentage of sugar shown by fall and spring tests and the difference between the two*—Continued

Tag. No.	Fall test.	Spring test.	Difference.	Tag No.	Fall test.	Spring test.	Difference.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
	20.2	15.2	5.0	585	19.8	15.4	4.4
	20.4	15.2	5.2	588	19.2	13.8	5.4
	20.2	16.6	3.6	589	19.6	15.6	4.0
	19.0	16.0	3.0	590	20.6	15.8	4.8
	18.6	15.8	2.8	591	19.4	16.4	3.0
	20.6	16.2	4.4	592	20.0	16.6	3.4
	20.0	17.0	3.0	594	19.4	15.8	3.6
	18.8	14.2	4.6	595	20.6	17.4	3.2
	20.6	15.4	5.2	596	18.6	15.2	3.4
	19.6	16.0	3.6	598	21.0	17.0	4.0
	19.0	16.6	2.4	602	20.0	16.2	3.8
	21.4	17.0	4.4	603	21.0	15.4	5.6
	20.8	15.6	5.2	604	18.8	15.6	3.0
	18.8	15.2	3.6	605	19.6	14.8	4.8
	20.8	16.2	4.6	606	18.6	16.0	2.6
	21.0	16.0	5.0	607	20.0	15.6	4.4
	20.6	15.6	5.0	608	18.6	16.2	2.4
	21.8	18.4	3.4	609	19.2	15.8	3.4
	20.4	15.0	5.4	610	22.4	18.2	4.2
	21.4	16.6	4.8	611	20.6	16.0	4.6
	20.8	17.4	3.4	613	20.6	17.4	3.2
	19.6	14.8	4.8	614	18.8	15.4	3.4
	20.0	16.0	4.0	615	19.2	15.4	3.8
	20.0	16.0	4.0	616	18.8	15.4	3.4
	16.0	15.8	.2	618	19.8	17.8	2.0
	18.4	13.8	4.6	626	17.6	14.6	3.0
	20.4	16.6	3.8	627	20.0	17.2	2.8
	19.6	14.8	4.8	630	18.8	15.6	3.2
	19.2	14.8	4.4	635	18.4	17.0	1.4
	20.8	15.6	5.2	636	21.4	17.4	4.0
	20.8	15.8	5.0	637	20.4	16.0	4.4
	21.8	17.2	4.6	638	20.2	18.0	2.2
	20.8	16.4	4.4	640	18.6	15.0	3.6
	19.6	16.8	2.8	642	19.4	16.2	3.2
	19.6	16.0	3.6	643	19.8	16.4	3.4
	19.4	16.2	3.2	644	21.2	17.6	3.6
	19.6	16.4	3.2	645	20.6	16.4	4.2
	20.4	16.0	4.4	646	19.4	16.4	3.0
	20.4	15.0	5.4	647	19.8	17.0	2.8
	20.6	17.2	3.4	648	20.4	17.0	3.4
	20.8	14.6	6.2	649	19.0	15.0	4.0
	21.2	16.4	4.8	650	19.6	15.6	4.0
	20.4	16.0	4.4	651	20.4	16.6	3.8
	21.8	15.6	6.2	652	20.0	17.4	2.6
	19.6	14.6	5.0	656	19.8	16.4	3.4
	20.2	16.2	4.0	660	22.4	18.6	3.8
	20.8	16.8	4.0	662	19.8	15.2	4.6
	20.4	16.0	4.0	668	19.6	16.0	3.6
	20.8	17.0	3.0	670	17.6	15.2	2.4
	18.6	15.4	3.2	671	18.4	15.2	3.2
	20.0	15.6	4.4	672	18.8	16.6	2.2
	21.4	15.8	5.6	673	17.8	14.6	3.2
	20.6	18.0	2.6	675	18.4	14.6	3.8
	20.2	15.4	4.6	676	20.6	16.2	4.4
	19.4	15.6	3.8	681	19.8	15.6	4.2
	19.6	16.2	3.4	683	19.6	15.2	4.4
	19.2	16.0	3.2	690	20.0	16.2	3.8
	19.6	14.6	5.0	692	19.8	17.0	2.8
	19.8	16.6	3.2	703	17.4	14.4	3.0

TABLE I.—*Percentage of sugar shown by fall and spring tests and the difference between the two*—Continued

Tag. No.	Fall test.	Spring test.	Difference.	Tag No.	Fall test.	Spring test.	Difference.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
707	20.0	18.8	1.2	774	19.8	16.6	3.2
709	19.8	14.2	5.6	775	20.4	17.2	3.2
712	19.8	17.2	2.6	776	20.8	15.8	5.0
715	18.6	15.4	3.2	777	20.4	18.0	2.4
716	21.0	17.0	4.0	778	20.0	15.8	4.2
717	18.6	15.2	3.4	779	19.6	15.6	4.0
718	18.0	15.2	2.8	780	19.6	17.6	2.0
719	20.2	15.6	4.6	781	18.8	15.0	3.8
720	19.0	14.4	4.6	782	19.4	14.0	5.4
721	18.8	15.6	3.2	783	19.6	15.0	4.6
722	19.2	14.8	4.4	784	19.6	14.6	5.0
723	19.8	14.8	5.0	785	20.6	15.6	5.0
724	18.4	14.6	3.8	786	17.6	14.2	3.4
725	18.4	13.2	5.2	787	18.0	16.6	1.4
726	19.2	16.2	3.0	788	19.0	15.6	3.4
727	19.8	14.0	5.8	789	21.2	17.2	4.0
728	17.0	14.0	3.0	790	17.8	14.0	3.8
730	19.4	15.4	4.0	791	18.2	14.2	4.0
731	17.4	14.0	3.4	792	16.8	12.2	4.6
732	17.2	13.6	3.6	793	18.4	16.0	2.4
733	18.8	15.0	3.8	794	19.4	16.6	2.8
734	17.6	15.6	2.0	795	17.8	14.6	3.2
735	16.6	14.8	1.8	796	18.8	16.8	2.0
736	18.6	16.2	2.4	797	18.0	15.9	3.0
738	17.2	14.6	2.6	798	17.4	14.2	3.2
739	18.8	14.8	4.0	799	20.4	14.8	5.6
740	19.4	15.6	3.8	800	21.6	17.0	4.6
741	21.6	17.2	4.4	801	22.4	16.8	5.6
742	20.4	16.2	4.2	802	19.2	16.8	2.4
743	18.8	13.6	5.2	803	19.6	16.2	3.4
744	20.4	16.2	4.2	804	19.4	14.8	4.6
746	20.0	15.6	4.4	805	19.6	17.0	2.6
747	20.0	18.6	1.4	806	19.4	16.6	2.8
748	21.2	17.2	4.0	807	18.8	14.6	4.2
749	18.0	13.2	4.8	808	20.0	16.8	3.2
750	20.6	15.8	4.8	809	18.6	15.0	3.6
751	18.4	14.8	3.6	810	19.0	14.6	4.4
752	19.6	14.8	4.8	811	19.2	13.0	6.2
753	22.4	16.2	6.2	812	20.6	14.6	6.0
754	19.8	15.6	4.2	813	19.8	15.8	4.0
755	19.8	16.6	3.2	814	19.4	14.2	5.2
756	19.4	16.4	3.0	815	19.4	15.2	4.2
757	20.0	17.0	3.0	816	17.4	15.4	2.0
758	19.0	14.6	4.4	817	20.6	16.8	3.8
759	20.8	15.4	5.4	818	20.6	15.2	5.4
760	18.8	15.6	3.2	819	18.6	13.8	4.8
761	17.8	14.8	3.0	820	19.4	14.6	4.8
762	19.6	15.6	4.0	821	20.4	15.6	4.8
763	19.6	16.2	3.4	822	19.6	14.4	5.2
764	20.2	17.2	3.0	823	19.8	17.2	2.6
765	20.4	17.2	3.2	824	20.6	17.4	3.[illegible]
766	19.0	16.4	2.6	826	21.0	17.6	3.[illegible]
767	21.2	17.6	3.6	827	20.8	17.8	3.[illegible]
768	20.4	16.4	4.0	828	18.0	13.8	4.[illegible]
769	20.8	17.8	3.0	829	21.0	17.6	3.[illegible]
770	20.8	16.8	4.0	830	19.6	16.0	3.[illegible]
771	19.6	16.4	3.2	831	19.6	15.2	4.[illegible]
772	21.4	16.2	5.2	832	18.2	15.4	2.[illegible]
773	21.6	17.6	4.0	833	19.4	16.4	3.[illegible]

ABLE I.—*Percentage of sugar shown by fall and spring tests and the difference between the two*—Continued

Tag No.	Fall test.	Spring test.	Difference.	Tag No.	Fall test.	Spring test.	Difference.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
4	19.6	17.8	2.8	893	20.6	17.4	3.2
5	20.4	17.0	3.4	894	20.0	16.2	3.8
6	18.8	14.8	4.0	895	22.2	17.6	4.6
7	20.4	16.2	4.2	896	20.6	16.0	4.6
8	19.0	16.2	2.8	897	20.4	17.0	3.4
9	19.6	14.0	5.6	898	21.0	17.0	4.0
0	18.2	14.4	3.8	899	20.8	17.6	3.2
1	20.0	15.4	4.6	900	20.0	17.2	2.8
2	18.6	15.0	3.6	901	20.2	15.8	4.4
3	17.4	14.0	3.4	902	20.4	15.8	4.6
4	18.8	15.8	3.0	903	21.0	17.6	3.4
5	20.4	16.8	3.6	904	19.8	16.8	3.0
6	21.2	17.8	3.4	905	20.0	16.8	3.2
7	20.0	17.0	3.0	906	15.8	14.6	1.2
8	18.4	14.0	4.4	907	19.0	16.4	2.6
9	19.0	16.0	3.0	909	18.8	16.6	2.2
0	20.4	17.2	3.2	910	20.6	17.2	3.4
1	19.0	15.6	3.4	911	21.6	16.4	5.2
2	21.2	17.0	4.2	912	20.0	16.8	3.2
3	20.0	17.6	2.4	913	21.0	16.6	4.4
4	20.4	18.0	2.4	914	19.4	16.4	3.0
5	21.6	17.6	4.0	915	20.6	15.4	5.2
6	20.2	16.0	4.2	916	22.2	17.2	5.0
7	20.2	17.6	2.6	917	19.8	16.0	3.8
8	19.8	16.0	3.8	918	17.8	15.8	2.0
9	21.6	16.6	5.0	919	18.0	15.2	2.8
0	18.0	17.2	.8	920	20.8	17.4	3.4
1	19.4	15.0	5.4	921	21.0	18.2	2.8
2	20.8	16.8	4.0	922	20.0	16.2	3.8
3	19.8	17.6	2.2	923	20.0	16.8	3.2
4	21.0	16.4	4.6	924	20.4	17.2	3.2
5	20.0	15.4	4.6	925	17.2	14.4	2.8
6	16.6	14.2	2.4	926	19.6	16.0	3.6
7	18.8	16.2	2.6	927	18.4	15.4	3.0
8	20.8	17.0	3.8	929	18.6	15.6	3.0
9	21.6	15.6	6.0	930	17.0	14.0	3.0
0	20.0	15.4	4.6	931	16.0	15.2	0.8
1	20.0	15.8	4.2	932	19.0	16.0	3.0
2	19.0	16.6	2.4	933	16.8	13.6	3.2
3	18.6	14.6	4.0	934	18.2	15.0	3.2
4	19.8	15.8	4.0	935	18.2	14.8	3.4
5	19.6	14.0	4.6	936	19.2	15.2	4.0
6	20.0	15.8	4.2	937	19.2	15.2	4.0
7	17.8	13.6	4.2	938	18.4	15.8	2.6
8	17.6	13.8	3.8	939	19.8	16.2	3.6
9	18.4	14.4	4.0	940	21.4	17.4	4.0
0	18.4	14.6	3.8	941	19.6	16.0	3.6
[illegible]	20.0	16.0	4.0	942	19.4	16.0	3.4
[illegible]	22.6	16.0	6.6	943	20.0	16.0	4.0
[illegible]	19.0	13.2	5.8	944	20.8	17.0	3.8
[illegible]	20.0	16.4	3.6	945	21.0	16.2	4.8
[illegible]	20.4	15.6	4.8	946	20.6	16.4	4.2
[illegible]	19.8	14.4	5.4	948	18.2	15.2	3.0
[illegible]	20.2	16.2	4.0	949	18.8	15.6	3.2
[illegible]	21.2	16.4	4.8	950	18.6	14.2	4.4
[illegible]	20.6	17.2	3.4	951	19.6	15.4	4.2
[illegible]	21.4	17.6	3.8	952	21.2	16.0	5.2
[illegible]	20.4	15.4	5.0	953	20.6	15.6	5.0
[illegible]	20.0	16.4	3.6	954	20.0	15.6	4.4

TABLE I.—*Percentage of sugar shown by fall and spring tests and the difference between the two*—Continued

Tag No.	Fall test.	Spring test.	Difference.	Tag No.	Fall test.	Spring test.	Difference.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
955	19.8	15.6	4.2	1014	19.2	15.4	3.[illegible]
956	19.2	15.0	4.2	1015	20.4	15.2	5.[illegible]
957	20.4	15.0	5.4	1016	18.4	15.0	3.[illegible]
958	20.0	17.6	2.4	1017	18.6	14.8	3.[illegible]
959	20.4	17.4	3.0	1018	20.0	16.6	3.[illegible]
960	18.4	15.8	2.6	1019	18.6	15.6	3.[illegible]
961	20.0	15.6	4.4	1020	18.8	14.8	4.[illegible]
962	20.0	15.8	4.2	1021	19.4	16.4	3.[illegible]
963	19.6	15.2	4.4	1022	20.0	14.8	5.[illegible]
964	20.0	17.0	3.0	1023	18.8	15.6	3.[illegible]
965	20.0	17.0	3.0	1024	20.0	17.4	2.[illegible]
966	19.2	15.6	3.6	1025	20.0	16.2	3.[illegible]
967	20.0	15.4	4.6	1026	19.0	14.8	4.[illegible]
968	18.6	14.6	4.0	1027	16.8	13.8	3.[illegible]
969	18.4	16.4	2.0	1028	20.4	16.6	3.[illegible]
970	18.6	15.0	3.0	1029	19.4	14.6	4.[illegible]
971	19.6	15.6	4.0	1030	19.0	15.0	4.[illegible]
972	21.2	17.8	3.4	1031	18.6	15.6	4.[illegible]
973	18.6	14.8	3.8	1032	20.2	16.6	3.[illegible]
974	17.2	14.8	2.4	1033	17.0	14.0	3.[illegible]
975	18.6	15.6	3.0	1034	21.0	17.4	3.[illegible]
976	20.4	15.0	5.4	1035	21.0	16.6	4.[illegible]
977	18.6	14.2	4.4	1036	19.0	16.2	2.[illegible]
978	17.4	13.8	3.6	1037	18.0	15.2	2.[illegible]
979	21.6	18.2	3.4	1038	18.0	15.4	2.[illegible]
981	19.2	16.0	3.2	1156	17.0	15.2	1.[illegible]
982	18.6	14.2	4.4	1171	16.8	15.6	1.[illegible]
983	19.6	15.6	4.0	1184	16.0	13.8	2.[illegible]
984	19.6	15.2	4.4	1193	16.6	15.0	1.[illegible]
985	19.8	15.4	4.4	1206	15.0	13.4	1.[illegible]
986	16.4	13.6	2.8	1207	17.6	15.4	2.[illegible]
987	18.8	16.4	2.4	1211	14.8	13.6	1.[illegible]
988	16.6	14.4	2.2	1212	15.6	14.2	1.[illegible]
990	20.0	15.6	4.4	1215	15.6	14.4	1.[illegible]
991	19.2	15.4	3.8	1216	17.6	15.8	1.[illegible]
992	16.8	13.4	3.4	1224	13.6	11.8	1.[illegible]
993	19.4	15.2	4.2	1226	15.2	14.8	[illegible]
994	20.2	16.0	4.2	1228	17.0	14.8	2.[illegible]
995	20.0	14.6	5.4	1231	15.8	15.2	[illegible]
996	19.0	15.2	3.8	1233	14.4	13.2	1.[illegible]
997	20.4	15.8	4.6	1245	18.4	16.2	2.[illegible]
998	20.0	16.4	3.6	1254	15.2	14.8	[illegible]
999	19.0	16.2	2.8	1255	17.4	16.4	1.[illegible]
1000	22.4	18.8	3.6	1256	15.6	14.2	1.[illegible]
1001	20.2	16.6	3.6	1257	16.8	15.4	1.[illegible]
1002	20.8	17.0	3.8	1258	17.0	14.8	2.[illegible]
1003	19.4	16.6	2.8	1259	17.4	15.8	1.[illegible]
1004	19.6	15.6	4.0	1266	16.2	14.0	2.[illegible]
1005	20.8	16.0	4.8	1272	16.6	14.4	2.[illegible]
1006	19.6	15.8	3.8	1273	16.8	14.6	2.[illegible]
1007	20.0	16.6	3.4	1282	16.8	15.4	1.[illegible]
1008	19.8	15.6	4.2	1289	17.2	14.2	3.[illegible]
1009	20.0	17.2	2.8	1302	17.6	15.6	2.[illegible]
1010	21.8	18.4	3.4	1315	16.4	14.6	1.[illegible]
1011	20.2	15.8	4.4	1318	18.6	15.4	3.[illegible]
1012	19.2	15.8	3.4	1323	14.6	12.6	2.[illegible]
1013	20.6	16.8	3.8	1328	16.8	15.2	1.[illegible]

The results here shown indicate that the difference in the percentage of sugar before and after storage is very irregular. In looking over this table one does not seem to find any relation whatsoever between the fall test and the difference in the percentage of sugar before and after storage. It is likewise difficult to see any relation between this difference and the spring test for any one beet. One could not derive the fall test of any beet from the spring test, and as a result, the breeder is at a loss to select from his spring-test data those beets that will test high at harvest time. It would therefore be quite impossible to breed up a strain of beets which would test high at harvest by making selections from spring tests.

In order to determine what relation exists between the percentage of sugar originally contained in the beet and the percentage which it loses during storage, correlation tables were made. Table II gives the correlation as determined from Friedl's analysis.

TABLE II.—*Correlation between percentage of sugar in beet and loss in percentage of sugar during storage*

Percentage of sugar in beet.	Loss in percentage during storage.																			
	0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75
1.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2.5	1	...	...	1	...	2	1	1	...	...	...	...	...	...	...	...	1	...	...	...
3.5	...	...	2	...	2	1	3	1	2	...	...	...	1	...	...	...	...	...	...	...
4.5	...	...	2	2	...	4	3	2	4	5	2	1	1	1	...	...	1	...	...	...
5.5	...	1	1	2	2	3	4	15	6	4	3	1	...	1	1	...	...	...	...	...
6.5	...	...	1	...	3	5	15	10	6	15	12	4	5	2	...	...	...	...	...	1
7.5	...	...	...	1	...	12	4	15	13	14	4	7	5	1	1	...	...	...	...	...
8.5	...	...	...	...	1	1	4	6	5	12	6	5	4	2	2	1	1	...	1	...
9.5	...	...	...	...	...	...	3	3	2	4	4	...	...	2	...	2	3	...	2	...
10.5	...	...	1	...	...	...	...	1	...	1	...	1	3	2	1	...	2	...	...	...
11.5	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...

The results shown in this table indicate a correlation value of 0.272 ±0.0338 between the percentage of sugar originally found in the beet and the decrease in percentage during storage.

The results from the analytical data of Table I are given in the following table:

TABLE III.—*Correlation between percentage of sugar in beet and loss in percentage of sugar during storage (from columns 2 and 4 of Table I)*

Percentage of sugar in beet.	Loss in percentage during storage.							
	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5
[illegible].5	......	1	......	......	......	......	......	......
[illegible].5	......	2	3	1	......	......	......	......
[illegible].5	3	9	4	1	......	......	......	......
[illegible].5	3	9	15	9	3	......	......	......
[illegible].5	2	8	28	46	11	1	......	......
[illegible].5	2	7	48	75	38	3	2	......
[illegible].5	......	......	34	79	60	15	1	1
[illegible].5	......	2	21	69	70	30	4	1
[illegible].5	......	......	4	20	27	10	3	......
[illegible].5	......	......	......	2	2	4	3	......
[illegible].5	......	......	......	......	......	......	......	......

The results here shown give a correlation coefficient of 0.462 $\pm$0.0188 between the percentage of sugar in the beet at harvest and the decrease in percentage in individual beets during storage.

These tables also indicate that the beets of high percentage at harvest tend to decrease more in percentage of sugar during storage than do the low-testing beets; as a consequence, beets of high test at harvest tend to be low in the spring, while beets of low test at harvest tend to be relatively high in the spring. The inclination on the part of the breeder is, therefore, to select the low fall-testing beets, since these show a relatively higher percentage of sugar at planting time. A breeder, for example, guided only by the spring-testing data (see Table I) would select for seed production the beets tagged 74, 103, 110, and 155 as the most desirable among the first 100 listed. In making his selections he would choose beets testing the highest according to his data—that is, beets showing 17 or more per cent of sugar. Now, on examining the fall tests one finds that there were really 11 beets containing 20 or more per cent of sugar. Their tag numbers are 39, 79, 101, 110, 119, 134, 140, 152, 154, 155, and 156. So our breeder would select two beets containing 20 per cent of sugar and would neglect nine other beets containing 20 to 21 per cent. With these two 20 per cent beets he would select two others of less than 20 per cent. Therefore, after a few years his lines should show a decrease in the average percentage of sugar.

Friedl did not give the weight of each beet along with the percentage of sugar which it contained, and, consequently, we do not know just how much of the decrease in sugar was due to the water intake of each beet during storage. He made dry weight determinations on other beets and found an increase of 6 per cent of water during storage which would correspond to about 1 per cent decrease in the percentage of sugar. Therefore, his results show that there was a too great difference between the fall and spring tests to be accounted for by decrease in the percentage of sugar (due to intake of water) and it is evident that there was also a marked loss of the actual sugar in the beet.

In the present work the order of weighing and sampling beets was arranged so that comparable weights and percentage of sugar were obtained for each beet. The order was as follows: First, sample (at harvest time), weight of sampled beet, storage for 98 days, weight of sampled beet; and second, sample (98 days after first sample was taken).

Table IV gives for each beet these weights before and after storage, the sugar content before and after storage, and the loss of sugar in grams during storage. The same tag numbers in this table and Table I denote identical beets. The sugar content of each beet before and after storage is the product of the weight and its corresponding percentage of sugar (from Table I). For example, beet tagged 1 before storage tested 19.0, weighed 1,100 gm. and contained 209 gm. of sugar; after storage this beet weighed 1,110 gm., tested 13.2, and contained 147 gm. of sugar.

TABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
1	1,100	209	1,110	147	62
2	1,330	231	1,475	186	45
4	1,385	221	1,520	191	30
8	1,185	208	1,340	171	37
9	1,420	232	1,500	213	19
18	1,158	202	1,275	181	21
19	1,810	264	1,960	243	21
20	825	153	825	123	30
22	890	162	960	140	22
23	1,495	263	1,600	227	36
24	1,289	229	1,420	199	30
25	1,382	240	1,530	227	22
27	1,625	273	1,725	214	59
28	1,275	217	1,362	174	43
29	1,385	233	1,500	210	23
30	976	164	1,037	145	19
31	1,420	256	1,525	207	49
35	1,255	203	1,360	199	4
36	795	137	900	126	11
39	1,105	221	1,110	184	37
41	825	149	905	130	19
44	1,380	264	1,440	233	31
46	1,100	194	1,200	175	19
47	1,155	203	1,237	168	35
48	1,015	174	1,075	142	32
49	1,245	224	1,310	186	38
4	955	160	1,040	146	14
5	1,080	175	1,175	172	3
6	1,344	236	1,530	220	16
8	1,105	192	1,205	157	35
0	719	126	825	125	1
4	1,312	257	1,300	221	36
8	800	139	860	120	19
9	1,040	218	1,125	178	40
1	1,112	216	1,061	157	59
4	1,720	265	1,900	262	3
6	910	166	1,000	144	22
7	1,152	180	1,025	162	18
8	1,090	190	1,125	175	15
9	1,585	282	1,725	248	34
0	890	153	930	136	17
1	1,305	217	1,362	185	32
2	1,460	234	1,575	220	14
3	2,060	379	2,085	292	87
4	775	149	800	131	18
5	1,090	181	1,140	146	35
6	880	144	900	144	0
7	1,270	221	1,260	204	17
8	1,585	292	1,680	255	37
9	1,178	217	1,250	187	30
00	830	158	850	136	22
01	970	194	990	162	32
02	745	144	760	117	27
03	1,430	263	1,510	269	6
04	965	177	990	162	15
06	917	158	1,000	154	4
09	965	183	1,040	168	15
10	1,090	222	1,110	200	22

TABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
111	995	175	1,065	153	22
113	1,820	320	1,920	276	44
114	1,670	293	1,775	270	23
115	1,600	250	1,620	204	46
116	1,705	310	1,620	253	57
117	1,690	308	1,740	154	154
119	730	150	870	141	9
120	1,205	219	1,300	177	42
121	1,190	224	1,310	194	30
122	1,220	227	1,325	191	36
123	1,085	185	1,160	165	20
124	1,080	201	1,180	170	31
125	1,120	211	1,370	216	+5
126	1,350	265	1,520	237	28
127	1,240	218	1,575	236	+18
128	1,620	253	1,650	238	15
129	1,170	222	1,250	200	22
130	980	180	1,020	169	11
131	1,235	220	1,350	189	31
132	870	160	935	146	14
133	1,425	274	1,500	225	49
134	1,020	204	1,050	149	55
137	1,530	248	1,620	207	41
138	1,085	189	1,150	149	40
139	1,070	201	1,200	194	7
140	1,260	260	1,312	215	45
141	1,395	215	1,450	186	29
142	1,715	295	1,775	166	29
143	880	162	950	159	3
144	1,515	218	1,650	175	43
145	1,640	315	1,755	281	34
146	1,420	241	1,575	214	27
147	1,090	194	1,130	169	25
148	850	163	887	145	18
149	860	162	875	142	20
150	1,335	245	1,390	209	36
151	1,200	216	1,210	189	27
152	1,560	312	1,725	266	46
153	1,105	203	1,200	182	21
154	1,070	220	1,170	187	33
155	1 015	207	1,050	180	27
156	770	155	850	133	22
157	815	166	850	127	39
158	1,400	266	1,500	234	32
159	1,400	272	1,400	218	54
160	1,390	270	1,462	209	61
165	1,115	198	1,200	180	18
168	945	170	930	154	16
173	940	169	1,012	148	21
174	1,330	231	1,500	219	12
175	970	167	1,075	150	17
176	1,220	222	1,275	204	18
177	770	142	770	134	8
178	930	182	940	158	24
180	1,560	271	1,690	254	17
183	850	173	915	150	23
186	1,155	236	1,190	205	31
190	1,380	243	1,425	242	1

'ABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
91	1,080	229	1,110	209	20
92	1,670	331	1,725	279	52
93	930	177	975	156	21
94	1,320	269	1,525	238	31
95	1,670	336	1,720	306	30
96	1,140	228	1,187	145	83
97	1,210	254	1,280	215	39
98	1,335	256	1,400	224	32
99	1,415	283	1,480	266	17
00	1,170	241	1,320	203	38
01	1,545	284	1,570	251	33
02	1,110	233	1,154	201	32
03	1,025	180	1,062	151	29
05	1,470	288	1,450	252	36
06	1,180	224	1,260	192	32
07	1,035	175	1,080	147	28
08	1,200	216	1,300	177	39
09	1,070	222	1,110	175	47
10	1,380	264	1,515	236	28
11	1,110	229	1,125	198	31
12	1,100	183	1,125	164	19
13	980	196	1,040	166	30
14	1,040	185	1,075	150	35
15	1,325	249	1,375	217	32
16	1,580	271	1,700	241	30
17	1,255	221	1,350	184	37
18	1,270	267	1,360	218	49
19	1,220	234	1,300	200	34
20	1,450	261	1,500	222	39
21	640	111	650	86	25
22	795	132	890	103	28
23	810	149	850	126	23
24	595	107	637	85	22
25	760	117	800	1,010	7
26	870	164	950	114	49
27	800	157	890	139	18
28	945	164	950	141	23
29	1,040	212	1,150	179	33
30	1,030	189	1,065	162	28
31	780	152	820	128	24
32	950	192	987	158	34
33	875	182	900	158	24
34	900	184	900	160	24
35	960	198	1,020	169	29
36	730	142	800	125	17
37	1,330	239	1,360	204	35
38	850	168	890	149	19
39	1,230	207	1,320	195	12
40	850	160	930	143	17
41	1,025	219	1,110	200	19
42	860	159	870	141	18
43	870	174	900	156	18
44	900	173	925	153	20
45	1,090	198	1,162	179	19
46	1,110	231	1,200	204	27
47	930	193	1,025	170	23
48	990	188	1,035	157	31
49	1,015	203	1,000	174	29

TABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd.

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
250	1,460	274	1,470	235	39
252	1,060	206	1,150	184	22
253	900	176	962	150	26
254	915	176	1,050	157	19
255	980	182	1,005	161	21
256	725	139	825	132	7
257	1,330	247	1,450	209	38
258	905	166	950	146	20
259	810	157	875	143	14
260	1,150	202	1,230	209	+7
261	1,100	202	1,160	172	30
262	1,135	224	1,210	198	26
263	940	182	1,040	162	20
264	895	166	912	131	35
265	1,830	344	1,850	307	37
266	1,560	296	1,575	261	35
267	1,270	249	1,375	231	18
268	2,000	372	2,050	328	44
269	1,090	203	1,150	179	24
270	1,375	253	1,375	214	39
271	855	164	830	121	43
272	1,305	256	1,425	233	23
273	1,380	254	1,415	204	50
274	2,120	368	2,200	330	38
275	1,530	288	1,650	261	27
276	950	160	1,010	129	31
278	825	160	870	136	24
279	1,005	183	1,080	166	17
280	1,335	251	1,400	224	27
281	825	145	890	125	20
283	1,350	224	1,355	182	42
286	1,520	286	1,700	252	34
287	2,160	341	2,300	322	19
288	1,295	259	1,420	222	37
289	1,450	273	1,525	250	23
290	1,630	284	1,700	244	40
291	910	176	980	149	27
292	1,360	245	1,437	195	50
293	1,815	352	1,900	315	37
294	1,080	199	1,115	165	34
295	1,290	261	1,370	233	28
296	985	215	1,010	196	25
297	1,685	320	1,825	281	49
298	1,280	241	1,375	223	18
299	1,490	277	1,580	250	27
300	1,220	248	1,275	214	34
305	1,800	299	1,960	282	17
306	1,415	263	1,500	240	23
307	1,735	323	1,760	292	31
308	1,525	265	1,650	231	34
309	1,735	312	1,850	307	5
310	1,010	186	1,000	156	30
311	930	169	1,040	158	11
312	1,585	292	1,700	262	30
313	885	154	870	136	18
314	1,735	312	1,875	270	42
317	1,405	284	1,500	249	35
321	1,340	265	1,470	229	36

TABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
23	980	182	1,060	159	23
25	1,020	177	1,087	151	26
26	1,240	216	1,290	191	25
27	1,280	241	1,362	190	51
29	1,060	214	1,100	187	27
32	1,050	199	1,237	198	1
35	1,180	250	1,100	196	54
37	980	184	1,110	151	33
40	770	145	865	126	19
41	1,105	190	1,225	171	19
43	930	158	1,015	150	8
46	870	169	960	144	25
49	815	174	850	153	21
52	1,175	207	1,150	159	48
54	1,190	236	1,225	152	84
56	1,135	204	1,225	181	23
57	920	189	1,000	164	25
58	1,705	259	1,800	223	36
65	1,110	173	1,170	159	14
66	1,200	230	1,320	206	24
68	900	178	920	150	28
69	750	148	850	129	19
70	1,280	230	1,350	213	17
71	1,270	226	1,375	198	28
73	1,080	227	1,175	204	23
75	975	179	1,000	158	21
76	1,275	235	1,325	199	36
79	1,155	222	1,275	194	28
80	980	178	1,060	157	21
81	820	154	875	129	25
82	975	175	1,025	164	11
83	885	166	950	154	12
85	1,075	193	1,160	162	31
86	705	142	800	121	21
87	835	172	850	144	28
88	1,340	265	1,400	232	33
91	790	171	880	137	34
93	1,015	191	1,110	171	20
94	915	170	1,050	157	13
95	1,090	185	1,150	147	38
96	1,010	200	1,037	176	24
98	805	161	850	146	15
00	900	180	940	147	33
01	915	170	965	145	25
02	1,165	233	1,280	212	21
03	950	165	1,030	144	21
04	810	138	860	117	21
05	970	182	1,050	155	27
06	845	145	900	121	24
07	945	150	980	131	19
10	965	187	1,050	164	13
12	640	109	675	93	16
13	720	121	750	93	28
15	1,110	202	1,175	183	19
16	885	174	950	154	20
17	1,055	188	1,050	166	22
19	990	143	1,040	129	14
20	1,340	247	1,425	211	36

TABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd.

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
423	800	150	910	129	21
425	795	159	900	128	31
429	910	164	1,000	146	18
430	900	180	990	160	20
432	960	188	1,050	166	22
435	990	204	1,060	180	24
436	1,230	266	1,290	245	21
439	1,285	260	1,030	181	79
440	925	196	1,040	171	25
444	940	165	1,000	138	27
445	820	184	890	150	34
446	1,352	257	1,400	216	41
449	860	175	875	154	21
450	990	204	1,050	168	36
451	1,190	254	1,225	220	34
452	1,858	364	1,900	323	41
455	1,052	221	1,175	183	38
457	1,098	193	1,175	174	19
459	1,074	223	1,150	189	34
462	1,390	286	1,460	245	41
464	950	198	1,050	178	20
469	750	156	800	125	31
470	1,000	208	1,125	175	33
471	1,390	261	1,425	230	31
472	1,050	231	1,050	168	63
473	1,370	274	1,462	196	78
474	1,180	248	1,260	227	21
475	1,090	231	1,140	187	44
477	675	144	700	120	24
478	1,090	224	1,250	180	44
479	960	205	1,025	174	31
480	1,120	217	1,200	202	15
482	680	151	712	115	36
484	1,010	218	1,050	197	21
488	1,117	240	1,100	176	64
492	1,130	199	1,270	157	42
494	2,050	377	2,000	313	64
497	820	166	900	137	29
498	1,005	205	1,125	171	34
501	1,076	220	1,100	183	37
503	1,240	236	1,300	208	28
505	1,260	234	1,350	213	21
506	780	161	870	141	20
507	830	166	850	144	22
508	850	160	925	131	29
509	835	172	925	142	30
510	1,160	227	1,150	184	43
511	1,330	253	1,350	224	29
512	650	139	668	112	27
514	780	162	850	133	29
515	1,250	235	1,325	201	34
516	1,460	303	1,490	241	62
517	690	144	790	126	18
519	900	185	987	154	31
520	745	162	790	145	17
521	791	161	880	132	29
522	815	187	900	149	38
523	1,220	253	1,275	222	31

ABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
25	850	167	910	135	32
27	830	166	890	142	24
28	1,340	268	1,375	220	48
29	1,055	169	1,075	170	1
30	910	167	1,000	138	29
31	1,020	208	1,075	178	30
32	995	195	1,075	159	36
35	870	167	925	137	30
39	1,020	212	1,050	164	48
40	1,000	208	1,070	169	39
41	620	135	700	120	15
42	780	162	825	135	27
44	1,110	217	1,125	189	28
48	865	168	900	146	22
49	660	129	725	119	10
51	660	129	725	126	3
52	860	175	900	144	31
55	805	164	900	135	29
56	1,280	264	1,337	230	34
58	1,020	212	1,187	173	39
59	870	184	1,012	166	18
60	1,110	226	1,150	184	42
62	820	179	940	147	32
63	1,105	217	1,210	177	40
64	990	200	1,100	178	22
65	875	182	940	158	24
66	900	184	937	150	34
67	745	155	850	144	11
69	1,120	208	1,275	196	12
70	750	150	825	129	21
71	950	203	1,200	190	13
73	710	146	725	130	16
75	940	188	975	150	38
76	840	163	875	136	27
77	1,150	225	1,200	194	31
79	960	184	1,012	162	22
81	1,180	231	1,250	183	48
84	1,260	248	1,300	216	32
85	1,000	198	1,040	160	38
88	1,225	235	1,350	186	49
89	1,100	216	1,210	189	27
90	960	198	1,050	166	32
91	1,375	267	1,400	230	37
92	1,080	216	1,190	197	19
94	920	178	1,010	160	18
95	1,740	350	1,862	324	34
96	1,530	285	1,675	254	31
98	990	208	1,050	179	29
02	910	182	920	149	33
03	980	206	1,100	169	37
04	1,000	188	1,075	170	18
05	1,080	212	1,212	179	33
06	1,130	211	1,225	196	15
07	1,100	220	1,162	165	55
08	1,680	312	1,725	279	33
09	1,285	247	1,350	213	34
10	660	148	675	123	25
11	1,020	210	1,140	182	28

TABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd.

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
613	1,180	243	1,210	210	33
614	1,010	190	1,110	171	19
615	760	146	825	127	19
616	830	156	850	131	25
618	1,145	227	1,150	204	23
626	1,325	233	1,575	230	3
627	880	176	925	159	17
630	1,325	250	1,425	222	28
635	1,220	224	1,325	225	+1
636	1,385	296	1,436	232	64
637	870	177	950	152	25
638	970	196	1,000	180	16
640	1,450	270	1,550	232	38
642	830	161	900	146	15
643	1,385	274	1,460	239	35
644	930	197	970	171	26
645	960	198	1,075	176	22
646	830	161	825	135	26
647	815	161	875	149	12
648	1,200	245	1,240	211	34
649	1,020	194	1,050	158	36
650	1,840	361	1,900	296	65
651	1,180	241	1,260	209	32
652	1,450	290	1,475	257	33
656	1,130	224	1,200	197	27
660	950	213	910	169	44
662	955	189	1,040	158	31
668	540	106	600	94	12
670	1,215	214	1,310	199	15
671	780	143	825	125	18
672	820	154	885	147	7
673	1,130	201	1,200	175	26
675	925	161	975	142	19
676	970	201	1,025	166	35
681	1,150	227	1,225	191	37
683	975	191	1,100	167	24
690	1,150	230	1,180	191	39
692	1,400	277	1,500	255	22
703	1,170	205	1,300	187	18
707	1,230	246	1,260	237	9
709	1,005	198	1,125	160	38
712	1,280	254	1,310	225	29
715	1,500	294	1,725	265	29
716	1,070	225	1,130	192	33
717	1,145	214	1,225	186	28
718	1,630	294	1,700	268	26
719	1,100	222	1,225	191	31
720	1,150	218	1,200	173	45
721	1,480	278	1,650	258	20
722	930	179	1,000	148	31
723	1,270	252	1,450,	215	37
724	1,200	221	1,320	193	28
725	1,400	258	1,475	195	63
726	1,170	226	1,225	199	27
727	1,200	238	1,320	185	53
728	1,470	250	1,575	220	30
730	1,340	260	1,500	231	29
731	1,360	237	1,450	203	34

ABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
2	1,380	237	1,450	197	40
3	1,130	212	1,225	184	28
4	1,280	225	1,325	207	18
5	1,370	228	1,425	211	17
6	1,230	228	1,310	212	16
8	1,300	224	1,560	228	4
9	1,600	301	1,675	248	53
0	2,360	461	2,350	366	95
1	1,110	240	1,240	213	27
2	1,540	316	1,725	279	37
3	1,230	232	1,400	190	42
4	1,040	213	1,150	186	27
6	1,120	224	1,220	190	34
7	1,195	239	1,212	225	14
8	970	207	1,000	172	35
9	1,500	270	1,590	210	60
0	1,060	218	1,125	178	40
1	1,500	276	1,690	250	26
2	1,130	222	1,262	187	35
3	1,230	276	1,290	209	67
4	970	192	950	148	44
5	1,020	203	1,040	173	30
6	1,450	281	1,500	246	35
7	1,380	276	1,390	238	38
8	1,220	233	1,287	188	45
9	1,125	234	1,200	182	52
0	980	184	1,025	160	24
1	960	171	1,040	154	17
2	1,040	204	1,100	172	32
3	713	149	825	134	15
4	1,260	254	1,337	230	24
5	1,040	212	1,075	185	27
6	990	188	962	158	35
7	800	170	825	145	20
8	970	199	1,075	176	23
0	1,025	213	1,090	183	30
9	835	174	880	156	18
1	1,620	318	1,625	266	52
2	960	206	1,100	178	28
3	920	200	1,000	176	24
4	910	180	975	162	18
5	1,355	277	1,435	246	31
6	790	164	875	138	26
7	850	173	887	159	14
8	1,140	228	1,300	205	23
9	730	143	800	125	18
0	960	188	970	171	17
1	940	178	1,060	159	19
2	890	173	937	131	42
3	800	157	840	126	31
4	900	176	1,000	146	30
5	1,060	218	1,200	187	31
6	1,170	207	1,250	177	30
7	1,320	238	1,350	224	14
8	1,185	226	1,275	199	27
9	1,050	223	1,075	185	38
0	1,060	189	1,130	158	31
1	890	162	940	133	29

TABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd.

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
792	1,200	202	1,225	149	53
793	1,585	292	1,575	252	40
794	1,160	225	1,200	199	26
795	1,530	272	1,600	233	39
796	1,230	231	1,325	222	9
797	1,475	265	1,490	224	41
798	870	152	910	129	23
799	820	167	970	144	23
800	970	210	1,037	176	34
801	1,020	230	1,050	176	54
802	1,205	231	1,275	214	17
803	860	169	900	146	23
804	910	178	950	141	37
805	1,030	202	1,075	183	19
806	990	192	1,025	170	22
807	1,050	197	1,150	168	29
808	1,000	200	1,125	189	11
809	1,325	247	1,360	204	43
810	1,100	209	1,212	177	32
811	1,080	208	1,200	156	52
812	1,750	360	1,775	259	101
813	1,040	206	1,125	178	28
814	1,000	194	1,150	149	45
815	750	145	800	121	24
816	1,190	207	1,250	192	15
817	980	202	1,075	180	22
818	920	190	1,062	161	29
819	1,420	264	1,550	214	50
820	1,130	219	1,275	186	33
821	965	197	1,060	165	32
822	1,010	198	1,130	163	35
823	1,600	317	1,575	270	47
824	1,010	208	1,050	183	25
826	1,470	309	1,520	267	42
827	970	202	1,025	182	20
828	1,130	203	1,200	165	38
829	1,110	233	1,130	199	34
830	1,150	225	1,225	196	29
831	1,720	338	1,737	264	74
832	1,605	292	1,727	268	24
833	1,530	296	1,650	270	26
834	1,675	328	1,737	292	36
835	1,160	237	1,162	197	40
836	1,770	334	1,920	284	50
837	1,400	286	1,562	253	33
838	1,800	342	1,850	300	42
839	1,390	272	1,510	211	61
840	1,020	186	1,080	155	31
841	1,180	236	1,325	204	32
842	1,400	260	1,500	225	35
843	1,290	224	1,400	196	28
844	1,210	228	1,300	205	23
845	1,460	298	1,510	254	44
846	1,200	254	1,275	227	27
847	1,560	312	1,625	276	36
848	1,950	359	1,980	277	82
849	1,775	338	1,850	296	42
850	1,380	282	1,405	241	41

ABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
51	1,170	222	1,250	195	27
52	935	198	1,000	170	28
53	1,085	217	1,125	198	19
54	1,030	210	1,050	189	21
55	1,070	231	1,150	202	29
56	1,020	206	1,050	168	38
57	1,200	242	1,225	215	27
58	1,230	243	1,370	219	24
59	1,060	229	1,175	195	34
60	1,575	283	1,600	275	8
61	1,230	238	1,350	202	36
62	1,110	231	1,190	200	31
63	1,345	266	1,380	242	24
64	1,310	275	1,420	233	42
65	1,140	228	1,287	198	30
66	1,270	212	1,300	185	27
67	1,030	194	1,050	170	24
68	1,170	244	1,262	214	30
69	1,045	226	1,275	199	27
70	1,040	208	1,187	183	25
71	1,200	240	1,225	194	46
72	820	156	825	137	19
73	1,230	228	1,360	198	30
74	1,180	234	1,225	193	41
75	920	180	1,030	144	36
76	1,150	230	1,225	193	36
77	1,190	212	1,370	186	26
78	920	163	950	131	32
79	760	140	800	115	25
80	1,100	202	1,200	175	27
81	1,070	214	1,170	187	27
82	1,250	282	1,375	220	62
83	840	159	925	122	37
84	1,830	366	1,960	305	61
85	1,090	222	1,160	181	41
86	1,040	206	1,130	163	43
87	1,200	242	1,295	210	32
88	880	186	870	143	23
89	860	177	925	159	18
90	1,270	273	1,320	232	41
91	1,050	214	1,150	177	37
92	1,180	236	1,300	213	23
93	1,060	218	1,125	196	22
94	830	166	850	138	28
95	830	184	900	158	26
96	1,130	233	1,262	202	31
97	830	169	875	149	20
98	1,150	242	1,270	216	26
99	930	193	990	174	19
00	1,110	222	1,100	189	33
01	950	192	1,030	163	29
02	880	179	920	145	34
03	1,090	229	1,112	196	33
04	1,095	217	1,150	193	24
05	1,230	246	1,225	206	40
06	1,210	192	1,275	186	6
07	1,550	294	1,590	261	33
08	1,200	226	1,250	208	18

TABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
910	1,000	206	1,020	175	31
911	1,240	268	1,240	203	65
912	980	196	1,050	176	20
913	870	184	950	158	26
914	1,070	208	1,150	189	19
915	770	160	850	131	29
916	950	211	1,025	176	35
917	840	166	875	140	26
918	1,250	222	1,315	208	14
919	1,730	310	1,775	270	40
920	1,060	220	1,060	184	36
921	1,000	210	1,050	191	19
922	1,070	214	1,120	181	23
923	1,105	221	1,150	193	28
924	1,480	302	1,450	249	53
925	1,210	208	1,230	177	31
926	850	167	900	144	23
927	1,330	245	1,400	216	29
929	1,145	213	1,200	187	26
930	1,420	242	1,450	203	39
931	1,000	160	1,000	152	8
932	1,255	238	1,300	208	30
933	1,185	199	1,275	173	26
934	1,305	237	1,375	206	31
935	1,640	299	1,700	252	47
936	1,260	242	1,325	202	40
937	1,330	255	1,275	194	61
938	1,000	184	1,000	158	26
939	1,775	351	1,875	304	47
940	1,220	261	1,240	216	45
941	1,440	282	1,300	208	74
942	1,160	225	1,300	208	17
943	1,160	232	1,275	204	28
944	1,160	242	1,275	217	25
945	1,075	226	1,237	201	25
946	1,160	239	1,200	197	42
948	1,420	258	1,512	230	28
949	1,450	273	1,450	226	47
950	1,020	191	1,100	156	35
951	1,060	196	1,100	168	28
952	890	189	990	158	31
953	1,140	235	1,220	190	45
954	850	170	925	144	26
955	910	180	970	151	29
956	875	168	950	142	26
957	960	196	1,075	161	35
958	980	196	1,025	180	16
959	1,200	245	1,212	211	34
960	1,020	189	1,075	170	19
961	1,075	215	1,200	187	28
962	810	162	925	146	16
963	1,220	239	1,325	202	37
964	1,510	302	1,525	259	43
965	1,210	242	1,275	216	26
966	1,190	229	1,275	199	30
967	1,030	206	1,150	177	29
968	1,150	214	1,250	182	32
969	1,305	240	1,380	226	14

TABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
70	1,245	232	1,390	209	23
71	1,190	234	1,320	206	28
72	1,260	267	1,250	222	45
73	1,130	210	1,220	180	30
74	1,920	330	2,025	300	30
75	1,620	301	1,630	254	47
76	970	199	1,060	159	40
77	1,450	270	1,550	220	50
78	1,365	238	1,435	198	40
79	1,425	308	1,450	264	44
81	1,425	274	1,410	226	48
82	1,100	205	1,200	171	34
83	1,030	202	1,100	172	30
84	1,350	265	1,420	216	49
85	1,330	264	1,425	219	45
86	1,370	225	1,450	197	28
87	1,425	268	1,475	252	16
88	1,540	256	1,620	233	23
90	1,025	205	1,100	171	34
91	1,350	259	1,420	219	40
92	1,170	197	1,250	168	29
93	1,280	248	1,400	212	36
94	1,030	208	1,062	170	38
95	1,125	225	1,275	186	39
96	1,380	262	1,450	220	42
97	1,140	234	1,260	199	35
98	1,350	270	1,362	223	47
99	1,375	261	1,460	237	24
00	1,290	289	1,320	248	41
01	980	198	1,650	174	24
02	1,275	265	1,330	226	39
03	1,360	265	1,430	237	28
04	1,410	276	1,525	238	38
05	1,170	243	1,200	192	51
06	1,210	237	1,320	208	29
07	1,400	280	1,430	237	43
08	1,670	331	1,675	261	70
09	1,350	270	1,450	250	20
10	1,110	242	1,125	207	35
11	1,030	208	1,120	177	31
12	1,220	234	1,315	207	27
13	920	189	1,000	168	21
14	1,400	269	1,525	235	34
15	1,225	250	1,370	208	42
16	1,150	212	1,260	189	23
17	1,320	246	1,475	218	28
18	960	192	1,030	171	21
19	1,330	248	1,375	215	33
20	1,200	226	1,270	188	38
21	1,075	208	1,150	188	20
22	1,150	230	1,275	189	41
23	1,120	210	1,200	187	23
24	1,690	338	1,680	292	46
25	1,290	258	1,375	223	35
26	1,020	194	1,120	166	28
27	1,390	234	1,450	200	34
28	1,215	248	1,370	228	20
29	1,225	238	1,320	193	45
30	915	174	1,000	150	24

TABLE IV.—*Loss of sugar in grams by individual beets during 98 days' storage*—Contd.

Tag No.	Before storage.		After storage.		Loss of sugar.
	Weight.	Sugar content.	Weight.	Sugar content.	
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
1031	1,220	227	1,325	207	20
1032	880	178	925	153	25
1033	1,220	208	1,300	182	26
1034	1,090	229	1,190	207	22
1035	1,050	220	1,110	184	36
1036	1,120	213	1,150	186	27
1037	1,655	298	1,680	255	43
1038	945	170	975	150	20
1156	1,540	262	1,550	236	26
1171	1,365	229	1,450	226	3
1184	1,275	204	1,275	176	28
1193	1,310	231	1,400	210	21
1206	1,240	186	1,225	164	22
1207	1,130	199	1,175	181	18
1211	1,230	256	1,650	224	32
1212	2,050	320	2,050	291	29
1215	1,010	167	975	140	27
1216	1,420	250	1,375	217	33
1224	1,365	185	1,350	159	26
1226	2,260	344	2,150	318	26
1228	1,860	316	1,850	274	42
1231	2,250	356	2,075	315	41
1233	790	114	800	105	9
1245	1,325	244	1,330	216	28
1254	2,340	356	2,350	348	8
1255	1,570	273	1,550	254	19
1256	1,400	218	1,425	202	16
1257	1,305	219	1,325	204	15
1258	1,480	252	1,480	219	33
1259	1,155	201	1,170	185	16
1266	1,490	241	1,475	206	35
1272	1,210	201	1,200	173	28
1273	1,530	257	1,500	219	38
1282	1,600	269	1,600	246	23
1289	1,180	203	1,160	165	38
1302	1,450	255	1,435	224	31
1315	1,315	213	1,325	193	20
1318	1,390	259	1,400	216	43
1323	1,160	169	1,175	148	21
1328	1,575	265	1,625	247	18

The results here given indicate that beets are irregular in gain or loss of weight during storage. Most of the beets gained slightly in weight. Some few remained constant as to weight, while others lost in weight. While the mere loss or gain in weight, due to water outgo or water intake has its effect upon the percentage of sugar, it does not influence the sugar content of the beet.

Of most consequence is the marked irregularity in the amount of sugar lost by individual beets during storage. This loss of sugar ranges from 0 to 154 gm.; that is, from 0 to 50 per cent of the total sugar content of the beet at harvest. Column 6 of Table IV gives the extent of this loss of sugar for each individual beet. Some of the reasons and conditions

leading to this loss of sugar will be given in a later paper on the storage of sugar beets.[4]

Table V gives the correlation between sugar content of beets and loss of sugar in grams during storage.

TABLE V.—*Correlation between sugar content of beet in grams and the loss of sugar during storage*

Sugar content in grams.	Loss of sugar in grams.							
	1 to 20	21 to 40	41 to 60	61 to 80	81 to 100	101 to 120	121 to 140	141 to 160
100 to 150	27	15	.....	.....	.....	.....	.....	.....
151 to 200	82	157	6	1	.....	.....	.....	.....
201 to 250	56	213	43	2	2	.....	.....	.....
251 to 300	12	86	32	10	.....	.....	.....	.....
301 to 350	2	13	19	3	.....	.....	.....	1
351 to 400	1	2	3	3	2	1	.....	.....
401 to 450	.....	.....	.....	.....	.....	.....	.....	.....
451 to 500	.....	.....	.....	.....	1	.....	.....	.....

The value of the coefficient is 0.476 ± 0.018, which indicates a practical certainty of correlation. The table shows in a general way the fallacy of testing sugar beets after storage and explains how a breeder's lines selected from such tests may continue to fall in sugar content with succeeding generations.

Table VI gives the correlation between the percentage of sugar in the beet at harvest and the loss of sugar in grams during storage. The value for $r = 0.366 \pm 0.020$.

TABLE VI.—*Correlation between percentage of sugar in beet and grams of sugar lost during storage*

Percentage of sugar in beet.	Loss of sugar in grams.															
	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80	80 to 90	90 to 100	100- to 110	110- to 120	120- to 130	130- to 140	140- to 150	150- to 160
13 to 14	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....
14 to 15	1	1	2	1	1	....	....	....	....	....	....	....	....	....	....	....
15 to 16	4	6	5	1	2	....	....	....	....	....	....	....	....	....	....	....
16 to 17	6	10	12	7	2	2	....	....	....	....	....	....	....	....	....	....
17 to 18	9	25	26	27	10	....	....	....	....	....	....	....	....	....	....	....
18 to 19	0	31	58	45	15	8	3	....	2	....	....	....	....	....	....	1
19 to 20	3	26	65	51	27	6	5	3	1	1	....	....	....	....	....	....
20 to 21	2	16	71	75	24	5	3	2	1	....	1	....	....	....	....	....
21 to 22	....	7	27	18	9	1	2	....	....	....	....	....	....	....	....	....
22 to 23	....	....	2	3	2	2	2	....	....	....	....	....	....	....	....	....

[4] PACK, D. A. STORAGE OF SUGAR BEETS. (Unpublished.) 1923.

DISCUSSION

Since sugar-beet factories cut their beets at harvest or after a short period of storage, the sugar-beet industry requires beets of high sugar content at harvest. This fact and the results of these investigations demand that our mother beets be tested in the fall after harvest. Since the average commercial sugar beet of the factories is stored 40 days on an average before cutting to make sugar, it might be advisable to test our breeding beets 40 days after harvest. In this event we should be selecting breeding beets which would be of high sugar content at harvest and have some storage qualities as well. Thus we would select with the expense of one testing those beets which would be most desired by the sugar companies. Under no circumstances would it appear advisable to make only one test on mother beets, and this test in the spring after the beets have been stored.

If there comes a time when sugar companies are forced to store their beets over extended periods, those having good storage qualities will be desired, in which event beets containing such qualities can be selected and bred up from consistent tests made before and after storage.

SUMMARY

1. Failure to recognize the erratic variations between tests of sugar beets at harvest time and after storage until the following spring has probably led to confusion in the selection of desirable strains of beets in sugar-beet breeding work.
2. Spring tests of sugar beets (made after the beets have been stored) are incomparable with the tests made at harvest. Spring tests are untrustworthy and give erroneous values for the quality of the beets at harvest.
3. Individual beets show great irregularity in the percentage and quality of sugar lost during storage.
4. Beets high in sugar and sugar content tend to lose more sugar during storage than do beets which are low in sugar and sugar content.
5. Since sugar-beet factories cut their beets at harvest or within an average period of storage of approximately 40 days, it appears that strains selected as desirable for breeding purposes should be considered on the basis of fall rather than of spring tests.
6. In order to understand clearly the comparative value of different strains of beets, the plant breeder should record both fall and spring tests and the conditions under which the beets were stored.

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